Geologic, Geomorphic and Chemical Characteristics of Wetlands Selected for Use in Biocriteria Development by the Montana Department of Environmental Quality

by

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1515 East 6th Avenue
Helena, MT 59620

for the

Montana Department of Environmental Quality
Water Quality Division

December, 1995

Project funding from the U.S. Environmental Protection Agency through the State Wetlands Protection Program, Section 104(b)(3) of the Clean Water Act

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Appendix C

Annotated Geologic and Hydrologic Bibliography of the DEQ Wetland Characterization Sites

ANNOTATED BIBLIOGRAPHY OF WETLAND SITE GEOLOGY

Alkali Lake.

Bibliographic Source: Geoindex lat-long search

Author: Coffin, D.L., A. Brietkrietz and R.G. McMurtry

Title: Surficial geology and water resources of the Tobacco and Stillwater River valleys, northwestern Montana

Series: Montana Bureau of Mines and Geology Bulletin 81

Date: 1971

Geologic mapping at scale of approx 1:84500 shows Alkali and Thirsty lakes underlain by Quaternary alluvium, but surrounded closely by till of unspecified age (presumably late Wisconsin). Most of catchment is probably underlain by till. Alluvium is likely thin, but no well records shown. No indications of till thickness or of underlying stratigraphy in Alkali Lake area. The bedrock outcrops are shown as Precambrian undivided. No quantitative descriptions of till source composition.

Water quality data include two conductivity measurements of 1230 (June 1968) and 1300 (October 1968) microsiemens/cm, and lab analysis from Thirsty Lake. Thirsty lake was several times more saline, much more sodic and depleted in sulfate relative to 1993 Alkali Lake.

Includes generalizations about ground-water quality in study area, no close by analyses but several from adjoining townships.

Bibliographic Source: Geoindex lat-long search

Author: Harrison, J.E., E.R. Cressman and J.W. Whipple

Title: Preliminary geologic and structure maps of part of the Kalispell 1 X 2 degree quadrangle, Montana

Series: USGS Open-file report 83-502

Date: 1983

Line map of bedrock geology at 1:250,000 scale showing the distribution of Belt series metasediments and structural relationships. Surficial sediments are only broadly differentiated

at this scale.

Bandy Reservoir

Bibliographic source: None - personal collection

Author: Dea, Peter

Title: Glacial geology of the Ovando Valley, Powell County, Montana

Series: University of Montana M.S. thesis in geology

Date: 1981

Detailed surficial geologic mapping at approximately 1:40,000 scale shows the Bandy Reservoir site underlain by glacial till deposited by the late Pleistocene Monture Creek advance. Description of the Monture till lithology indicates that matrix grain size is variable from sand to clay, and that limestone constitutes a significant minority of the larger clast sizes. Clast lithologies described (including limestone) reflect Proterozoic (Belt) formations exposed in the Monture Creek drainage.

Monture glacial deposits are interpreted as post-dating and truncating deposits of the Clearwater advance, originating from the Clearwater drainage to the northwest. Bandy Reservoir is near the western margin of mapped Monture Creek deposits, and may overlie Clearwater deposits (including possibly outwash) at depth. No stratigraphic information for this area is provided.

Bibliographic source: Geoindex lat-long search.

Author: Mudge, M.R., R.L. Earhart, J.W.Whipple and J.E.Harrison

Title: Geologic and structure map of the Choteau 1 degree X 2 degree quadrangle.

Series: U.S. geological Survey Miscellaneous Investigations Series Map I-1300

Date: 1982

Regional compilation of bedrock geology at 1:250,000 scale shows Monture Creek and the Clearwater Valley (both drainages may be contributing areas to glacial deposition at this site) underlain by outcrops of all Proterozoic Y (Belt) formations from the Helena Formation through the Bonner Quartzite. In addition, Monture Creek outcrops include both older (Empire and Spokane Formations) and younger (McNamara Formation) Belt units. Both drainages include large areas of the dominantly carbonate Helena Formation.

Beaver Creek

Bibliographic source: Geoindex lat-long search

Author: Witkind, I.J and W.M. Weber

Title: Reconnaissance geologic map of the Big Fork - Avon Environmental Study Area, Flathead, Lake, Lewis and Clark, Missoula and Powell Counties, Montana.

Series: USGS Miscellaneous Investigations Series Map I-1380

Date: 1982

Geologic mapping at 1:125,000 scale emphasizing surficial deposits shows the sampling site to be underlain by late Pleistocene till of the Placid Creek glacier. Till texture is described as coarse, with abundant cobbles and boulders in typically sandy or silty matrix. Soil drainage described as poor. Nearby Pre-Quaternary outcrops are mapped as undifferentiated Proterozoic Y (Belt). WNW trending normal faults (concealed beneath surficial deposits) traverse the area, and are shown as bracketing the wetland site. This document provides no direct hydrologic or hydrogeologic information.

Bibliographic source: Geoindex lat-long search.

Author: Mudge, M.R., R.L. Earhart, J.W.Whipple and J.E. Harrison.

Title: Geologic and structure map of the Choteau 1 X 2 quadrangle, western Montana.

Series: USGS Miscellaneous Investigations Series Map I-1300.

Date: 1982

Regional compilation of bedrock geology shows the pre-Quaternary

outcrops in the immediate area of the wetland to be composed of the Mount Shields Formation and Bonner Quartzite of Proterozoic Y (Belt) age. The Mount Shields Formation is dominantly argillitic and quartzitic, along with other noncalcareous lithologies. The Bonner Quartzite is dominantly feldspathic.

Upgradient areas presumed to have contributed sediment to the Placid Creek glacier include outcrops of the underlying Shephard and Mount Shields Formations, described as having minor limestone components but consisting primarily of argillite, siltite and minor quartzite. The contributing area does not appear to include outcrops of Helena Formation or other dominantly carbonate formations.

Bent Flat

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R. and R.L. Earhart

Title: Geologic map of the Bob Marshall and Great Bear Wildernesses and adjacent study areas, northwestern Montana.

Series: USGS Miscellaneous Investigations Series Map I-2181

Date: 1991

Regional mapping at 1:125,000 scale shows the Bent Flat area as undifferentiated glacial material and the ridges within the drainage as undifferentiated Cambrian (heavily carbonate lithologic descriptions) and Belt (Sheppard and Mount Shields Formations). Structures include a buried fault transecting Bent Flat, striking north-northwest. This is the most legible map compilation for the area.

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R. and R.L. Earhart

Title: Bedrock geologic map of part of the Northern Disturbed Belt, Lewis and Clark, Teton, Pondera, Glacier, Flathead, Cascade and Powell Counties, Montana

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-1375

Date: 1983

Regional bedrock mapping at 1:125000 scale is probably from the

same base as Mudge and Earhart (1991) cited above. Bedrock mapped beneath Bent Flat glacial cover (not shown) is a downdropped block of Devonian undifferentiated, ridges to the east are shown as Cambrian undifferentiated, with Bent Mountain relatively uplifted Belt (Mount Shields Formation). Both the Cambrian and Devonian sections are described as heavy in carbonates, with the Devonian sequence including evaporite-solution breccias.

Bibliographic source: Geoindex lat-long search

Author: Johns, W.M.

Title: Geology and mineral deposits of Lincoln and Flathead Counties, Montana

Series: Montana Bureau of Mines and Geology Bulletin 79

Date: 1970

Regional mapping at approximate scale of 1:125,000 shows Bent Flat underlain by undifferentiated glacial material. Bedrock mapping differs from later interpretations (Mudge and others) in showing lower slopes of ridges draining to Bent Flat as undifferentiated Devonian rather than Cambrian. Bent Mountain ridgetop is shown as undifferentiated Missoula Group (Belt). The Bent Flat buried fault of Mudge and Erhart is not shown.

Benton Lake.

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of glacial surface features at 1:500,000 scale shows Benton Lake just within the margin of maximum glacial advance, notwithstanding the glaciolacustrine sediments described by others as underlying the lake basin. This interpretation suggests that the surficial stratigraphy may include till as well as lacustrine sediments.

Bibliographic source: GeoIndex lat-long search

Author: Lemke, R.W.

Title: Geologic map of the Great Falls Quadrangle, Montana.

Series: USGS Geologic Quadrangle Map GQ-1414

Date: 1977

Map at scale of 1:62500 shows most of Benton Lake underlain by glaciolacustrine sediments of glacial Lake Great Falls. These are described as being as much as 100 feet in thickness in Benton Lake area, and in Benton Lake area consist predominantly of a plastic clay facies. Northern end of the lake is underlain by undifferentiated alluvium and colluvium.

The NW trending axis of the Sweetgrass Arch passes southwest of Benton Lake, elevating a large area of the Bootlegger member of the Blackleaf Formation in the southern part of the lake catchment. Interbedded sandstone, siltstone and shale with several bentonite beds.

North of the lake, mapping shows till cover (described as up to 70 feet thick) overlying the Marias River Shale. Three of the four members of the shale are described as calcareous at least occasionally, minor siltstone and sandstone interbeds within the Ferdig and Floweree members.

No hydrologic information. Uppermost predictable aquifer is probably the Kootenai Formation, underlying Blackleaf Fmn.

Bibliographic source: U.S.Geological Survey office inquiry

Author: Knapton, J.R., W.E. Jones and J.W. Sutphin

Title: Reconnaissance investigation of water quality, bottom sediment and biota associated with irrigation drainage in the Sun River area, west-central Montana

Series: U.S. Geological Survey Water-Resource Investigations report 87-4244

Date: 1987

This study included limited ground-water sampling in the Greenfields Bench gravels, and water quality, bottom sediment and biotic sampling of all of the Benton Lake pools. Ground water quality analyses include a high-selenium seep near Benton Lake.

Statistical summaries of the data and a comprehensive bibliography are included.

Bibliographic source: Inquiry to U.S. Geological Survey

Author: Lambing, J.H., D.A. Nimick, J.R. Knapton and D.U. Palwski

Title: Physical, chemical and biological data for detailed study of the Sun River Irrigation Project, Freezout Lake Wildlife Management Area, and Benton Lake National Wildlife Refuge, west-central Montana, 1990-92, with selected data for 1987-89.

Series: U.S. Geological Survey Open-file report 94-120

Date: 1994

This document contains descriptions of the data collection programs initiated in and around Freezout and Benton Lakes in 1990, and tabulations of soil, surface water and ground water, lake sediment and bioassay data. Interpretation of these data is pending.

The data assembled include a continuous record of specific conductance of the Lake Creek inflow, water quality and bottom sediment analyses from pools #1, 2, 3 and 5, and groundwater analyses and drill-hole descriptions from the vicinity of a saline seep along the west shore, and additional ground water analyses from water-supply wells.

Big Lake

Bibliographic source: Geoindex lat-long search

Author: Ellis, M.S.

Title: Geologic map of the Powder River basin and surrounding area, Wyoming, Montana, South Dakota, North Dakota and Nebraska

Series: USGS Miscellaneous Field Studies Map MF-2095

Date: 1989

Map scale (1:500,000) not particularly useful. Sampling location is at the extreme western limit of map coverage. The map is a compilation showing regional distribution of bedrock geologic units

(lots of Bearpaw, Judith River and Eagle Formations) and regional structure. These are the only usefulness of this map.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Feltis, R.D.

Title: Hydrogeologic map of the Billings 1 degree X 2 degree quadrangle and vicinity, Montana

Series: MBMG Hydrogeologic Map 9 A-F

Date: 1988

Regional compilation at 1:250,000 scale emphasizes outcrop distribution and structural contouring, with Stiff diagrams of water chemistry for different aquifers found within the quadrangle. The Big Lake topographic basin is shown to be along the eastern limb of the Lake Basin anticline, a hydrocarbon trap penetrated by numerous oil and/or gas wells. The Lake Basin anticline is shown intersecting the Lake Basin Fault Zone in the vicinity of Halfbreed Lake.

Mapping shows the Big Lake area to underlain by rocks above the base of the Eagle Sandstone (Map 9E) and below the base of the Lennep Sandstone (Map 9F). Surface of Bearpaw Shale is implied, but not shown as outcrop. (Bearpaw Formation is shown by Ross, Andrews and Witkind (1955) at 1:500,000 scale.)

Stiff diagrams (Map 9E) indicate nearby analyses of the Virgelle sandstone (of the Eagle Formation), the uppermost consolidated aquifer in the area, exceed 2000 mg/l TDS and are sodium chloride or sodium bicarbonate/chloride in composition. (The analyses displayed probably reflect mainly oilfield waters.)

<u>Big Sandy DOT Mitigation Wetland</u>

Bibliographic Source: Geoindex lat-long search

Author: Lindvall, R.M.

Title: Geology of the Big Sandy Quadrangle, Montana

Series: USGS Miscellaneous Geologic Investigations Map I-130

Date: 1956

Geologic mapping at 1:62,500 emphasizing surficial geology and glacial features. Sampling site is shown very near the contact of alluvium/colluvium material filling the preglacial Missouri channel and "ground moraine". Ground moraine in the quad is described as compact and of low permeability. The till is shown as 60 feet thick near Big Sandy.

Nearby wells shown, indicating the fill within the channel is on the order of 100 feet thick. Stratigraphic relationship between the till and the alluvium/colluvium is unclear from the map.

Bedrock formations underlying the surficial deposits are the Upper Cretaceous Clagget Shale (sandy in the upper 150 feet) and the overlying Judith River Formation. The immediate area of the site is underlain by the Claggett.

The map includes a qualitative summary of the engineering characteristics of the map units. Permeabilities of the undifferentiated alluvium/colluvium are described as highly variable. Permeability of the till and Claggett are very low. The site is near the edge of the sheet, so the distribution of map units in most of the upgradient Big Sandy Creek basin is not shown, although Cretaceous bedrock units must dominate the basin.

Bibliographic source: Geoindex lat-long search

Author: Swenson, F.A.

Title: Geology and ground-water resources of the lower Marias irrigation project, Montana.

Series: USGS Water-Supply Paper 1460-B

Date: 1957

Geologic mapping at a scale of 1:94500 emphasizes surficial geology. The general area of the site is mapped as paludal, described as plastic clay and silt. This map unit covers several sections in this part of the pre-glacial Missouri channel. The valley margin, possibly underlying the site, is mapped as a kame terrace with unclear(?) stratigraphic relationship to the paludal silts.

Isopach map included in the text shows the total thickness of unconsolidated deposits exceeding 200 feet near Boxelder, without coverage of Big Sandy. Interesting observations about the retention and infiltration of water entering the Lonesome Lake Basin. Page 51 includes table showing 6 years of monthly discharge data from Big Sandy Creek 2.5 miles SE of Big Sandy (pre-irrigation project - did the irrigation intended ever happen??).

Page 63 includes a description of the kame terrace and esker deposits near the sampling site, some of which are well sorted and mined for gravel. [Kame terrace likely elevated above water table??] Page 65 includes a description of the paludal deposits, characterized as "extremely fine-grained" and unlikely to yield much water to wells. Paludal deposits are also described "relatively thin", but no values are given. Description of conditions in 1946 indicate that high water table and capillarity caused visible surficial salt concentrations near the sampling site.

Water quality analyses from Quaternary aquifers in the pre-glacial Missouri channel (copied) contain dissolved solids up to 2600 mg/l. Na:Ca+Mg ratios are high in the higher-TDS water of the Missouri channel, lower in alluvial fan deposits.

A shallow observation well was maintained within the sample site quarter-section (28-13-5dd), with bimonthly measurements from 1946-1953, with water levels ranging from about 4.5 to >11.5 feet during the period of record. Spring peaks, winter minimum levels.

Bibliographic source: Geoindex lat-long search

Author: Pierce, W.G. and C.B. Hunt

Title: Geology and mineral resources of north-central Choteau, western Hill and eastern Liberty Counties, Montana.

Series: USGS Bulletin 847-F

Date: 1937

Mapping at a scale of about 1:125,000 with Big Sandy at the extreme eastern edge of the coverage. Generalized bedrock only, with no surficial geology shown. This document is of historical interest only, adds nothing to useful to information about surficial materials or hydrology.

Black Coulee

Bibliographic source: Geoindex lat-long search

Author: Zimmerman, E.A.

Title: Preliminary report on the geology and ground-water

resources of northeastern Blaine County, Montana

Series: MBMG Bulletin 19

Date: 1960

This is one of the more minimal MBMG Bulletins ever published. Generalized geologic map at scale of about 1:125,000 shows general geologic setting to be till (ground moraine) overlying upper Cretaceous rocks. There are outcrops of Bearpaw Shale within the site section, but map scale is uninformative. Probably shaley till overlying marine shale. Portions of the wetland complex probably are in contact with alluvium, but aquifer characteristics of alluvium are probably not generous unless stratified glacial materials are involved.

No water quality from the site township.

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of surficial glacial features at 1:500,000 scale shows Black Coulee apparently within a band of marginal morainal deposits ringing the Turner-Hogeland plateau. This deposit is presumably(?) related to the glacial advance which did not override the bench, rather than to the advance responsible for the glacial deposits ("ground moraine") shown on the bench surface.

Blackfoot Meadows

Bibliographic source: Geoindex lat-long search

Author: Ruppel, E.T.

Title: Geology of the Basin quadrangle, Jefferson, Lewis and Clark and Powell Counties, Montana

Series: USGS Bulletin 1151

Date: 1963

This map emphasizes the igneous units of the quadrangle (mapped at 1:48000) and provides no real information on unconsolidated deposits. All the unconsolidated deposits along the upper Little Blackfoot are mapped as glacial undivided - seems questionable. The exposed igneous units in the immediate vicinity of Blackfoot Meadows are mapped as rhyolite flows, flow breccias and tuffs of Tertiary age, with some underlying Cretaceous Elkhorn Volcanics (welded tuff facies) also exposed. The basin above Blackfoot Meadows is underlain dominantly by felsic volcanics, many tufaceous.

Blackfoot WPA

Bibliographic source: U.S. Geological Survey bibliographic search of the Blackfoot valley area.

Author: Weber, M.W. and I.J. Witkind

Title: Reconnaissance geologic map of the western half of the Marcum Mountain quadrangle, Powell County, Montana

Series: U.S. Geological Survey Open-file report 79-445

Date: 1979

Detailed surficial geologic mapping at 1:24,000 scale shows the Blackfoot WPA site underlain by "Older Pinedale" outwash(?) of late Pleistocene age. Outwash materials are described as moderately well sorted in character. Outwash surface appears to merge into the modern Blackfoot River floodplain just south of the WPA.

Upland outcrops within the contributing drainage basin are mapped as undifferentiated Proterozoic (Belt) formations.

Bibliographic source: Geoindex lat-long search

Author: Wallace, C.A.

Title: Generalized geologic map of the Butte 1 degree X 2 degree sheet, Montana

Series: U.S. Geological Survey Miscellaneous Field Studies Map MF-1925.

Date: 1987

Regional bedrock geologic compilation at 1:250,000 scale shows the contributing surface-water basin underlain by undifferentiated

Ravalli Group (Spokane, Empire and Greyson Formations) of Proterozoic (Belt) age. Nearby areas are shown as underlain by granodiorite of Late Cretaceous age and by intermediate to mafic volcanic rocks of Eocene and Oligocene (early to mid Tertiary) age. [Mineralization can be inferred from the presence of the intrusive body and from the local name "Mineral Hill".]

Brush Lake and White Lake

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Reiten, J.C.

Title: Water quality of selected lakes in Sheridan County, Montana

Series: MBMG Open-file report 244

Date: 1991(?)

This publication describes the results of a 1990 survey of the water quality of more than 50 lakes in Sheridan County, with comparisons to previous (1984) field surveys of lake specific conductance. The lakes sampled include Brush Lake, Mallard Pond, White Lake, North Goose, North Widgeon Slough and Lone Tree. Limited geochemical interpretations include the development of an empirical "contamination index" based on molar ratios of chloride ion to other anions.

A poor-quality map at approximately 1:125,000 scale shows classification of the sampled lakes according to a 5 - class system based on specific conductance.

Bibliographic source: Montana Bureau of Mines and Geology Publication Index

Author: Donovan, J.J.

Title: Ground-water geology and high-yield aquifers of northeastern Montana.

Series: MBMG Open-file report 209

Date: 1988

This document is the most current and comprehensive investigation of the northeastern Montana gravel aquifers which interact with many lakes and wetlands in the area, including the wetland sampling program sites of Brush Lake, White Lake, Mallard Pond, Gaffney Lake

and Medicine Lake. This publication includes analyses of water chemistry and aquifer characteristics and their general relationships with surface water. Regional water budget analyses are described with a MODFLOW two dimensional model of the Clear Lake and tributary aquifers. Historical records of ground-water elevations are included.

Map coverage at 1:100,000 scale shows the interpreted extent of high-yield gravel aquifers with respect to lakes of the region.

Bibliographic source: None - personal collection

Author: Donovan, J.J.

Title: Geochemical and hydrologic dynamics in evaporative groundwater-dominated lakes of glaciated Montana and North Dakota

Series: Doctoral dissertation, Pennsylvania State University

Date: 1992

The geochemistry of Brush and White Lakes is described in detail in this dissertation. Field data include detailed geochemistry of ground water, lakes, and sediments. Mass balance relationships (water and solutes) for Brush Lake are derived from geochemical and hydrogeologic arguments. Post-Pleistocene historical development of the modern Brush Lake/White Lake geochemistry is modeled.

The analysis includes interpretations of regional climate and groundwater mechanisms with relevance to other Sheridan County sample program sites.

Bibliographic source: Geoindex lat-long search

Author: Witkind, I.J.

Title: Quaternary Geology of the Smoke Creek - Medicine Lake - Grenora Area, Montana and North Dakota.

Series: USGS Bulletin 1073

Date: 1959

Geologic mapping at 1:62,500 scale shows both lakes underlain by Late Wisconsin ("Mankato") outwash. The lakes are situated near the confluence of the Stady and Grenora channels, with the till ridge between the two extending northeastward from the lakes. White Lake is nearer to the (southern) boundary of the

Stady/Grenora channel, with Brush Lake near the midpoint. A major esker trends eastward from a point northeast of White Lake. There is some limited geophysical and other subsurface information which is probably all superseded by later MBMG and USGS hydrogeologic work.

Burns Creek

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of glacial surface features at 1:500,000 scale shows the Burns Creek site at the margin of the maximum extent of glaciation across the Burns Creek drainage. This mapping shows outwash deposition above the North Fork-Middle Fork confluence and below the sample site, with a gap between. The North Fork Burns Creek drainage way is shown as continuous with the Fox Creek-Redwater Creek drainage to the north.

According to this interpretation, glacially transported calcareous materials may underlie both the Burns Creek system and Fox Lake, both of which are underlain by noncalcareous (Fort Union Formation) bedrock.

Bibliographic source: Geoindex lat-long search

Author: Prichard, G. E. and E.R. Landis

Title: Coal resources and Cenozoic geology of the Girard coal field, Richland County, Montana

Series: USGS Bulletin 1310

Date: 1975

Geologic mapping at 1:62,500 scale includes the North Fork of Burns Creek at the southwesternmost corner of the map area, some distance upstream of the sampling site. The North Fork above the alluvium is shown as the Tongue River member of the Fort Union Formation, with areas of mappable clinker. Upland areas along divides have extensive areas mapped as the Flaxville Formation.

There is a fairly extensive discussion of geomorphology and Late Tertiary - Quaternary geology, but no discussion of hydrologic characteristics. The position of the mapped extent of Pleistocene glaciation with respect to the sample site is not shown.

Bibliographic source: Geoindex lat-long search

Author: Torrey, A.E. and F.A. Kohut

Title: Geology and ground-water resources of the lower Yellowstone River Valley, between Glendive and Sidney, Montana

Series: USGS Water-Supply Paper 1355

Date: 1956

Geologic mapping at 1:126,720 scale is restricted to the Yellowstone Valley and the lowermost sections of the tributaries. Lower Burns Creek is mapped as alluvium incised into till, with occasional outcrops of undivided Fort Union Formation shown along adjacent reaches of the Yellowstone.

Page 16 has a brief but interesting discussion of the behavior of tributaries, including Burns Creek, as drains for the irrigated terraces of the Yellowstone. There is no discussion of the hydraulic characteristics or water quality of the tributary alluvium.

Colter Campground

Bibliographic source: Geoindex lat-long search

Author: Elliot, J.E.

Title: Geologic map of the southwest part of the Cooke City Quadrangle, Montana and Wyoming.

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-1084.

Date: 1979

Detailed bedrock geologic mapping at 1:24000 scale shows the Colter Campground wetland underlain by "granitic rocks" (mainly granite gneiss) of Precambrian W age (approximately 2,750 m.y.). Surficial sediments are shown as a narrow (and presumably thin) band of

undifferentiated glacial deposits extending barely beyond the wetland. No description of the character of glacial deposits in the area is included.

Up-slope areas within the apparent surface catchment may include mafic metamorphic rocks (metadolerite) of Precambrian W age. Nearby outcrops of Cambrian-aged rocks (including the Meagher Limestone and other calcareous lithologies) appear to be outside of the surface catchment of the wetland site, but may have contributed material to the glacial sediments exposed at the site surface.

Comertown Preserve

Bibliographic source: Montana Bureau of Mines and Geology Publications Index.

Author: Bergantino, R.N.

Title: Quaternary geology of the Wolf Point 1 degree X 2 degree quadrangle.

Series: MBMG Open-file report 172

Date: 1986

Regional map compilation (blueline) at approximately 1:250,000 scale shows both Comertown and North Widgeon sites underlain by Late Wisconsin(?) till. [Regionally, this till deposit is typically described as having a significant fraction of calcareous material.] Mapping shows some isolated areas underlain by ice-contact stratified drift within the Lone Tree Lake 7.5' quadrangle.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index.

Author: Bergantino, R.N.

Title: Prequaternary geology of the Wolf Point 1 degree X 2 degree quadrangle.

Series: MBMG Open-file report 171

Date: 1986

Regional map compilation (blueline) at approximately 1:250,000 scale shows surficial glacial materials of the Comertown Preserve and North Widgeon wetland sites to be underlain by undifferentiated Fort Union Formation of early Tertiary (Paleocene) age. This map

shows regional outcrop distribution only, and does not include any structural information or local lithologic descriptions.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index.

Author: Donovan, J.J.

Title: Ground-water geology and high-yield aquifers of northeastern Montana

Series: MBMB Open-file report 209

Date: 1988

Aquifer mapping at 1:100,000 scale shows Comertown Preserve to be well outside the distribution of high-yield gravel aquifers.

Condon Creek Proposed RNA, #1 and #2.

Bibliographic Source: Geoindex lat-long search.

Author: Mudge, M.R and R.L. Earhart

Title: Geologic Map of the Bob Marshall and Great Bear Wildernesses and Adjacent Study Areas, Northwestern Montana.

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-2181

Date: 1991

Map coverage at 1:125,000 scale covers the Swan Range above the site but not the lower slopes or lowland areas. Mapped formations upgradient of the wetland site include the Spokane formation, the Empire Formation and the Helena Formation (all Proterozoic Y in age) with the Late Proterozoic diorite occurring near the Swan divide.

The Spokane Formation is described as dominantly thin-bedded siltite with subordinate argillite and quartzite. The overlying Empire Formation (transitional between Spokane and Helena) is described as dominantly calcareous to dolomitic argillite, with subordinate dolomite and quartzite interbeds. The Helena Formation is described as mainly limestone, dolomite and calcitic dolomite,

with subordinate dolomitic siltite and argillite. Stromatolitic and oolitic beds and molar tooth structures described in upper portions of the unit. Dips are to the east at 25 to 40 degrees.

The upper portion of the range-front fan complex is mapped as a band of colluvium below the Proterozoic outcrops. No other information regarding surficial deposits of the sample site is provided.

Creedman Coulee

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of surfiicial glacial features shown the Creedman Coulee area underlain by till ("ground moraine").

Bibliographic source: None - default reference.

Author: Ross, C.P., D.A. Andrews and I.J.Witkind

Title: Geologic map of Montana

Series: U.S. Geological Survey, no series

Date: 1955

Statewide compilation at 1:500,000 scale shows the Creedman Coulee basin in Montana underlain mainly by the Bearpaw Shale of Late Cretaceous age, with some Late Cretaceous Judith River Formation underlying the western tributaries. The geology of the Canadian portion of the basin is not shown.

This map shows generalized prequaternary geology only, and provides no information regarding surficial deposits. Presumably the Creedman Coulee basin surficial materials are glacial deposits of unknown thickness and character.

Neither the Geoindex lat-long search nor manual searching of the Montana Bureau of Mines and Geology produced any more useful geologic map coverage for this area.

Dudley Slough

Bibliographic source: Geoindex lat-long search

Author: Coffin, D.L., A. Brietkrietz and R.G.McMurtrey

Title: Surficial geology and water resources of the Tobacco and upper Stillwater river valleys, northwestern Montana

Series: Montana Bureau of Mines and Geology Bulletin 81

Date: 1971

Regional map coverage at 1:84,500 scale shows the Dudley Slough site to be underlain by undifferentiated Belt metasediments, and outside the lowland areas of major glacial deposition.

Bibliographic source: Geoindex lat-long search

Author: Johns, W.M.

Title: Geology and mineral deposits of Lincoln and Flathead counties, Montana

Series: Montana Bureau of Mines and Geology Bulletin 79

Date: 1970

Regional mapping at 1:125,000 shows the general area of Dudley Slough crossed by the contact between the Siyeh Formation and the "Lower Piegan Unit". The Siyeh is described as dolomite and limestone, commonly pyritic. The Lower Piegan is dominantly argillite, often calcareous and sometimes with limestone lenses.

Bibliographic source: None - DHES collection

Author: Rabe, F.W., R.L. Bursik and E.B. Cantor

Title: Classification and monitoring of wetlands in established

and proposed natural areas.

Series: Project report on USDA Forest Service Intermountain Research Station Proposal #89009.

Date: 198?

This document provides a partial chemical anaysis for Dudley Sluogh from July 1988, a reported maximum depth of 6 meters, and biological inventory data.

Evans Lake

Bibliographic source: None - personal collection

Author: Dea, Peter

Title: Glacial geology of the Ovando Valley, Powell County, Montana

Series: University of Montana M.S. thesis in geology

Date: 1982

Detailed surficial geologic mapping at approximately 1:40,000 scale shows Evans Lake underlain by till of the late Pleistocene North Fork advance. Evans Lake is approximately 1 mile from the western limit of North Fork till as mapped by Dea. Dea's study focused on the deposits of the Clearwater and Monture advances, and does not attempt to interpret stratigraphic relationships between the North Fork till and the outwash deposits contacting the till. [The Copenhaver Park well log, if it exists, might clarify this relationship.] It is possible that marginal Monture Creek and/or North Fork outwash underlies Evans Lake at relatively shallow depths.

The Dry Gulch channel is not mapped separately from the North Fork till.

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R., R.L. Earhart, J.W. Whipple and J.E. Harrison

Title: Geologic and structure map of the Choteau 1 degree X 2 degree quadrangle, Western Montana.

Series: U.S. Geological Survey Miscellaneous Investigations Series

Map I-1300

Date: 1982

Regional compilation of bedrock geologic mapping at 1:250,000 scale shows the North Fork Blackfoot source area for the North Fork till to be underlain by Proterozoic (Belt) formations from the Spokane Formation through the Bonner Formation, including large areas of Helena Formation (dominantly carbonate lithologies) in the lower and middle basin. The upper basin includes areas of undifferentiated Cambrian and Devonian rocks.

Fox Lake

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of glacial surface features at 1:500,000 scale shows Fox Lake near the triple junction between a Redwater Creek-Fox Creek drainage channel and the North Fork Burns Creek channel. Two additional drainage ways are shown extending northwestward to near the drainage divide between the Missouri and Yellowstone drainages. The position of the maximium glacial advance is shown approximately along the drainage divide to the north, then turning due south and crossing Fox Creek just east of Fox Lake and lower Burns Creek. [The North Fork Burns Creek drainage way may have carried meltwaters during times when Fox Creek was impounded but Burns Creek was not.]

The map suggests that this drainage may have been an important one at times of near-maximum advance. Fox Creek and Fox Lake may be overdeepened and underlain in places by gravel sequences similar to Burns Creek.

Bibliographic source: Geoindex lat-long search

Author: Parker, F.S.

Title: The Richey - Lambert Coal Field, Richland and Dawson

Counties, Montana

Series: USGS Bulletin 847-C

Date: 1936

Geologic mapping at 1:62,500 scale shows the Fox Lake area underlain by Quaternary alluvium, undifferentiated between Holocene and Pleistocene. The mapped alluvium is continuous across modern divides to Redwater Creek to the west and the North Fork of Burns Creek to the south. The drainage development and sediment are likely of glacial origin, at least in part. The alluvium is described as being as much as 30 feet thick in Redwater Creek and other larger drainages. There is no discussion of hydraulic characteristics of map units.

Fox Lake was described at the time as perennial but seasonally highly variable in size, and surrounded by salinated flats during low-water periods.

The Redwater Creek - Fox Creek - North Fork Burns Creek channel is interpreted as a mid-Pleistocene (Illinoisan or Iowan) diversion channel of the Pleistocene Missouri River. [If this is correct, there may be substantial gravel deposits underlying the channel.] Lacustrine sediments related to ice-marginal impoundments are described in Redwater Creek (and may underlie Fox Lake also). The southern limit of glaciation is shown several miles to the north, on the Missouri side of the Yellowstone/Missouri divide.

Bedrock in the entire Fox Creek drainage is shown as the Tullock Member of the Fort Union Formation.

Freezeout Lake.

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of glacial surface features at 1:500,000 scale shows Freezeout Lake (shown as Greenfield Lake on this map)near the western limit of Glacial Lake Great Falls and outside of the maximum extent of glacial advance.

Bibliographic source : Geoindex lat-long search

Author: Mudge, M.R., R.L. Earhart, J.W.Whipple and J.E. Harrison

Title: Geologic and structure map of the Choteau 1 X 2 degree quadrangle, western Montana.

Series: MBMG Montana Atlas MA 3-A.

Date: 1982

The scale (1:250,000) limits the usefulness of this map to regional overview. Map shows the Freezeout (?) basin underlain throughout by glaciolacustrine deposits (of glacial Lake Great Falls?). The glaciolacustrine sediments on the sheet are described as up to 30 meters in thickness. Uplands to the north are shown as underlain by glacial materials overlying undivided Marias River Shale (Upper Cretaceous). Uplands to the west and south are shown as Marias River, Virgelle/Telegraph Creek and Two Medicine, all undivided, all upper Cretaceous and with the exception of the Virgelle all essentially non-aquifers.

Bibliographic source: Inquiry to U.S. Geological Survey

Author: Lambing, J.H., D.A. Nimick, J.R. Knapton and D.U. Palwski

Title: Physical, chemical and biological data for detailed study of the Sun River Irrigation Project, Freezout Lake Wildlife Management Area, and Benton Lake National Wildlife Refuge, west-central Montana, 1990-92, with selected data for 1987-89.

Series: U.S. Geological Survey Open-file report 94-120

Date: 1994

This document contains descriptions of the data collection programs initiated in and around Freezout and Benton Lakes in 1990, and tabulations of soil, surface water and ground water, lake sediment and bioassay data. Interpretation of these data is pending.

The data assembled include numerous drill-hole descriptions, ground-water level measurements and water quality analyses from the Greenfields Irrigation District south and east of Freezout, comprehensive water quality analyses from all Freezout Lake ponds, and bottom sediment analyses from two sites in the main lake and from Pond #1, and numerous soil analyses from irrigated and unirrigated areas south and east of the lake.

Bibliographic source: U.S.Geological Survey office inquiry

Author: Knapton, J.R., W.E. Jones and J.W. Sutphin

Title: Reconnaissance investigation of water quality, bottom sediment and biota associated with irrigation drainage in the Sun River area, west-central Montana

Series: U.S. Geological Survey Water-Resource Investigations report 87-4244

Date: 1987

This study included limited ground-water sampling in the Greenfields Bench gravels, and water quality and bottom sediment analyses from Pond #1 and from the south end of main Freezout Lake, and from Priest Butte Lake.

Statistical summaries of the data and a comprehensive bibliography are included.

Furnell WPA

Bibliographic source: Geoindex lat-long search

Author: Ross, C.P

Title: Fluorspar prospects of Montana

Series: USGS Bulletin 955-E

Date: 1950

Map coverage includes the Furnell area but emphasizes igneous map units only, does not provide information on the geology of the area East and Middle Buttes.

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of surficial glacial features at 1:500,000 scale

shows the till in the Furnell area to be part of a significant end moraine complex related to a glacial advance position extending through but not beyond the gaps between the buttes of the Sweetgrass Hills. Beyond the mapped extent of end moraine, this map shows till ("ground moraine"), presumably related to older glacial advances.

Bibliographic source: Montana State Library optical disk catalog

Author: Tuck, L.K

Title: Reconnaissance of geology and water resources along the north flank of the Sweet Grass Hills, north-central Montana

Series: U.S. Geological Survey Water-Resource Investigations Report 93-4026

Date: 1993

Reconnaissance geologic mapping at 1:100,000 scale shows the site overlying the shaley upper part of the Eagle Sandstone of Late Cretaceous age. The western part of the kettle field is shown underlain by Late Cretaceous Claggett Shale. Till underlying the sample wetland and adjacent kettles is not shown. The text states that glacial deposits typically do not exist much above 5000 feet, and probably do not exceed 50 feet in thickness in foothill areas (references include several on glacial geology). The Claggett Shale is described as "nearly impermeable" and as having bentonite beds, especially in it's lower portion.

Generalized potentiometric surfaces are mapped for the aquifers identified in the area (including the "interstratified sand and gravel aquifer" of glacial origins), but do not extend as far south as the sample site, where there do not appear to be any data.

Three chemical analyses from groundwater in glacial deposits between the sample wetland and Whitlash show calcium-bicorbanate (±sulfate) water types with total dissolved solids between 300 and 700 mg/l.

This publication includes what appears to be a thorough review of geologic literature pertinent to the Sweet Grass Hills, including some with relevance to the Oilmont Wetland site.

Bibliographic source: U.S. Geological Survey WRI 93-4026 (see Furnell WPA entry.)

Author: Lemke, R.W., W.M. Laird, M.J. Tipton and R.M. Lindvall

Title: Quaternary geology of the northern Great Plains in: The Quaternary of the United States; a review volume for the VII Congress of the International Association for Quaternary research.

Series: Princeton University Press

Date: 1965

This is a regional review of glacial and glaciolacustrine limits, regional depositional features and correlations. It does not describe glacial sediments in any detail, but does show the till in the gap of the Sweetgrass Hills as part of a "prominent end moraine" wrapped around the northern side of the range.

Gaffney Lake

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Donovan, J.J.

Title: Ground-water geology and high-yield aquifers of northeastern Montana.

Series: MBMG Open-file report 209.

Date: 1988

See Brush Lake entry for description of the publication. Regional isopach mapping of Clear Lake and pre-glacial terrace gravel aquifers shows Gaffney Lake overlying a relatively thick composite section of permeable aquifer material. Field data include 4 specific conductance measurements from different parts of Gaffney collected in 1984. Regional ground-water flow modeling indicates substantial ground-water discharge from the Clear Lake aquifer to Medicine Lake, also to Gaffney??

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Bergantino, R.N.

Title: Prequaternary geology of the Wolf Point 1 degree X 2 degree quadrangle.

Series: MBMG Open-file report 171

Date: 1986

Regional map compilation at 1:250,000 scale shows surficial deposits in the Gaffney Lake area underlain by undifferentiated Fort Union Formation of early Tertiary (Paleocene) age.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index.

Author: Bergantino, R.N.

Title: Quaternary geology of the Wolf Point 1 degree X 2 degree quadrangle.

Series: MBMG Open-file report 172

Date: 1986

Regional compilation at 1:250,000 scale shows Gaffney Lake straddling the contact between Late Wisconsin outwash deposits and an extensive area of ice-contact stratified drift (probably a kame terrace) occupying the southern margin of the Medicine Lake swale.

Bibliographic source: Geoindex lat-long search

Author: Witkind, I.J.

Title: Quaternary geology of the Smoke Creek-Medicine Lake-Grenora area, Montana and North Dakota.

Series: U.S. Geological Survey Bulletin 1073

Date: 1959

Hailstone and Halfbreed National Wildlife Refuges.

Bibliographic source: Shelf search of MBMG collection.

Author: Feltis, R.D.

Title: Hydrogeologic map of the Billings 1 X 2 quadrangle and vicinity, Montana

Series: MBMG Hydrogeologic Map 9

Date: 1988

The Billings 1 X 2 sheet (1:250,000) just barely includes Halfbreed and Hailstone (??) at it's northern margin. The maps shows outcrop area and Stiff diagrams of water quality for different aquifers, along with some subsurface structural information.

Map 9F, showing data for Upper Cretaceous through Quaternary aquifers, shows nothing for the Hailstone/Halfbreed area.

Map 9E, showing data from Eagle sandstone through the Bearpaw shale, shows the Eagle underlying both basins at depths of a few hundred feet. The few nearby chemical analyses shown from the Eagle and Judith River aquifers are sodic with subequal sulfate and bicarbonate concentrations and TDS up to 5300.

Map 9-D, showing the Dakota sandstone through Telegraph Creek Formations, shows top of Dakota sandstone at a depth of a couple of thousand feet. Chemical analyses shown indicate highly variable water quality, with Frontier Fmn analyses ranging up to 26400 mg/l but also down to less than 2000 mg/l. Dakota analyses similarly variable.

9-A through C provide data for older, deeper aquifers.

Hewitt Lake.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Perry, E.S.

Title: Geology and artesian water resources along Missouri and Milk Rivers in northeastern Montana.

Series: MBMG Memoir 11

Date: 1934

The emphasis of this outdated but interesting report is on the hydrologic and hydrogeologic impacts of the Fort Peck Reservoir and dam, under construction at the time. The document includes a generalized geologic map at a scale of about 1:125,000 showing the Hewitt Lake area underlain by undifferentiated formations "older than the Judith River Formation". [Apparently Claggett Shale.]

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Bergantino, R.N.

Title: Altitude of the top of the Claggett Shale, Glasgow 1 degree X 2 degree quadrangle.

Series: MBMG Open-file report 182

Date: 1987

Regional map at 1:250,000 scale shows Hewitt Lake and all of it's contributing drainage underlain by the Claggett Shale of Late Cretaceous age. Hewitt Lake overlies the apex of a structural dome (the Bowdoin Dome??), which presumably forms a structural trap for the hydrocarbons extracted from the underlying natural gas field.

This publication is a blueline map with no accompanying text or hydrologic information. Surficial deposits are not shown.

Homestead Lake.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index.

Author: Bergantino, R.N.

Title: Quaternary geology of the Wolf Point 1 degree X 2 degree quadrangle.

Series: MBMG Open-file report 172

Date: 1986

Regional compilation at 1:250,000 scale shows Homestead Lake underlain by undifferentiated "alluvium" of Big Muddy Creek. [Note that other sources indicate outwash deposits probably underlie the Big Muddy valley in this area - see Donovan, 1988.]

Bibliographic source: Montana Bureau of Mines and Geology Publications Index.

Author: Bergantino, R.N.

Title: Prequaternary geology of the Wolf Point 1 degree X 2

degree quadrangle.

Series: MBMG Open-file report 171

Date: 1986

Regional compilation at 1:250,000 scale shows Homestead Lake underlain by undifferentiated Fort Union Formation of Early Tertiary (Paleocene) age.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Donovan, J.J.

Title: Ground-water geology and high-yield aquifers of northeastern Montana.

Series: MBMG Open-file report 209.

Date: 1988

See Brush Lake entry for description of the publication. Mapping of aquifer distribution indicates that Homestead Lake is underlain by permeable aquifers of outwash and/or preglacial terrace gravel origins. Potentiometric data presented which indicate relatively efficient connections between Homestead Lake and terrace gravel aquifers nearby.

Hoskins Lake.

Bibliographic source: Geoindex lat-long search.

Author: Van Loenen, R.E.

Title: Geologic map of the Mount Henry roadless area, Lincoln County, Montana.

Series: Miscellaneous Field Studies Map MF-1534-A.

Date: 1984

Mapping at 1:50,000 scale shows the immediate area of Hoskins Lake

underlain by "alluvium" (more likely dominated by paludal and/or lacustrine deposits). Glacial deposits are shown along the margins of the Yaak valley and just to the south of the Hoskins Lake basin. Quite possible a veneer of glacial material beneath Hoskins Lake "alluvium". No discussion of the character of unconsolidated sediments.

Middle Belt outcrops are mapped on both sides of Hoskins Lake. The Middle Member of the Wallace Formation is shown on the ridge to the west and the lower slopes of the ridge to the east. The lower member of the Wallace is shown to the north, and the St. Regis Formation outcrops on the higher slopes of the ridge to the east. Both Wallace members contain limestone and dolomite interbeds, apparently more common in the lower member, within dominantly argillaceous sequences. The calcareous interbeds and lenses are described as frequently pyritic.

The lake basin overlies the trace of a north-south high angle fault, one of several such structures traversing the map area.

Bibliographic source: None - DHES collection

Author: Rabe, F.W. and S.Chadde

Title: Aquatic features of Research Natural Areas on the Kottenai and Flathead National Forests, Montana.

Series: None - USDA Forest Service(?) unnumbered report

Date: 1995

This document provides partial chemical analyses of Hoskins Lake and "Hoskins Pond" to the north, along with limited depth information from both. Field measurements showed modest vertical pH and salinity gradients in Hoskins Pond, with slightly higher dissolved solids and slightly lower pH near the pond bottom. The maximum measured depth near the center of Hoskins Pond was 8.5 meters, and the maximum depth along a single transect across the north end of Hoskins Lake was 7.5 meters. Drainage into and out of Hoskins Lake is described as intermittent (without supporting data).

The biological inventory of Hoskins Lake describes an abundance of the freshwater sponge **Spongilla lacustris.**

Indian Meadows.

Bibliographic source: Geoindex lat-long search.

Author: Mudge, M.R., R.L. Earhart, K.C. Watts, E.T. Tuchek and W.L.

Rice.

Title: Mineral resources of the Scapegoat Wilderness, Powell and Lewis and Clark Counties, Montana.

Series: USGS Bulletin 1385-B

Date: 1974

The Indian Meadows RNA is just off the southern edge of the mapped area. Contiguous areas are shown as undifferentiated glacial materials or as "gravels" without specified origins. Map scale of 1:96,000.

Upstream areas of this and adjacent drainages are mapped as entirely Precambrian Belt formations, with extensive areas of Helena Formation outcrop.

Bibliographic source: Geoindex latlong search

Author: Whipple, J.W., M.R. Mudge and R.L. Earhart

Title: Geologic map of the Rogers Pass area, Lewis and Clark County, Montana.

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-1642

Date: 1987

Excellent bedrock geologic map at 1:48000 scale shows outcrop on the north side of Indian Meadows (Lone Mountain) as Oligocene(?) /Miocene(?) sediments, described as dominantly clastic with minor marlstone and limestone, locally carbonaceous and locally tuffaceous. [Note that other references describe this unit as pyritic in this area.] Outcrops to the south of the wetland area are shown as tuff of the Oligocene(?) and Eocene Crater Mountain Volcanics. Structurally, the area is shown near the eastern edge of the Scapegoat thrust plate, with the (buried) Scapegoat thrust trace inferred to pass 1-2 miles to the east.

The Indian Meadows area proper is shown underlain by undifferentiated glacial deposits. Note that the modern contributing basin includes no mapped Belt or other Proterozoic units. However, glacial or glaciofluvial transport from the North Fork of Copper Creek undoubtedly contributed sediment derived from large areas underlain by the Proterozoic Y Helena Formation (dominantly calcareous and dolomitic) and the overlying Snowslip Formation (dominantly siltite and argillite), and probably from areas underlain by Cambrian and Devonian sediments, dominantly

calcareous and dolomitic in composition.

Bibliographic source: None - DHES collection

Author: Rabe, F.W., R.L. Bursik and E.B. Cantor

Title: Classification and monitoring of wetlands in established and proposed natural areas.

Series: Project report on USDA Forest Service Intermountain Research Station Proposal #89009.

Date: 198?

This document provides a partial chemical analysis from some site in Indian Meadows in June of 1987, along with biological inventory data. The location and site description are insufficient to confirm that the site or even the water body was the same as WET28.

Jarina

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of surficial glacial features at 1:500,000 scale shows the Jarina area near the eastward margin of the maximum extent of alpine glaciation, near the mapped narrow point of the unglaciated corridor between alpine and continental glacial margins.

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R. and R.L. Earhart

Title: Geologic map of the Bob Marshall and Great Bear Wildernesses and adjacent study areas, northwestern Montana

Series: USGS Miscellaneous Investigation Series Map I-2181

Date: 1991

Regional mapping at 1:125,000 scale appears to end at boundary of Bob Marshall Wilderness and proposed additions, and does not provide map coverage of the area.

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R. and R. L. Earhart

Title: Bedrock geologic map of the northern Disturbed Belt, Lewis and Clark, Teton, Pondera, Glacier, Flathead, Cascade and Powell Counties, Montana

Series: USGS Miscellaneous Investigations Series Map I-1375

Date: 1983

Regional mapping at 1:125,000 scale provides generalized coverage of sample area. Exposed units in the general area include the Saint Mary Formation, the Two Medicine Formation, undifferentiated Virgelle sandstone/Telegraph Creek Formation, and the Marias River Shale, all Upper Cretaceous in age. Five thrust faults traverse the general area, striking northwestward. The map scale is too small to be sure which of the map units underlie the sample site - possibly all of the above. The Bearpaw Shale is not mapped in the immediate area.

Lithologies described are dominantly fine-grained, with the Virgelle sandstone and interbeds within the Two Medicine Formation representing the most permeable-sounding lithologies, mudstones predominating elsewhere. Shallow to moderate dips to the southwest.

This map includes no information on hydrology or surficial geology.

Bibliographic source: Geoindex lat-long search

Author: Stebinger, E.

Title: Oil and gas geology of the Birch Creek - Sun River area, northwestern Montana

Series: USGS Bulletin 691-E

Date: 1918

Regional mapping at 1:125,000 scale includes the Jarina wetland area at the northern extremity of the map area. Till shown underlying most of the area, with the 'Horsethief Sandstone'

inferred to underlie the till beneath most of the area. [The Horsethief is a coarsening-upward transition from the underlying Bearpaw Shale, according to current use.] The text describes the Horsethief as massive and resistant. The Saint Mary Formation, also late Cretaceous, overlies the Horsethief and may underlie the western portion of the Jarina area. There is no specific information on the characteristics of the till or other surficial deposits shown.

Kingsbury WPA

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of surficial glacial features at 1:500,000 scale shows Kingsbury Lake (identified as Mallard Lake on this map) immediately south of the maximum extent of Pleistocene glaciation. The lake basin is shown to be within apparent ice-marginal drainage way connecting Lepley's Creek to the northwest, Kingsbury Lake and Flat Creek to Arrow Creek to the southeast. Other nearby lakes (Crane, Teal, Shonkin and Gravel) are shown as within the margin of maximum glacial advance. The divide between Kingsbury Lake and Geraldine is shown to have been glaciated.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Duaime, T.E., H.R. Moore, J.M. Holzer and G.A. Hockett

Title: Saline seep assessment of Geraldine, Montana and surrounding areas.

Series: MBMG Open-file report 169

Date: 1986

The study area for this research was limited to a radius of about 2.5 miles around Geraldine and thus does not include data from the Kingsbury Lake basin. It does include water quality data from shallow groundwater sources (wells and springs) and documents the

historical changes in ground-water quality in seep-impacted areas. The text includes qualitative but potentially useful interpretations of geochemical processes leading to seep development in this area.

Bibliographic source: Geoindex lat-long search

Author: Reeves, F.

Title: Thrust faulting and oil possibilities in the plains adjacent to the Highwood Mountains, Montana

Series: USGS Bulletin 806

Date: 1928

Regional geologic mapping at 1:250,000 scale covers the Kingsbury (aka Mallard) Lake area. Reeves shows Kingsbury Lake to be underlain by Colorado Shale and to be situated immediately south of the southern limit of glacial drift deposition. Dikes related to the Highwood Mountains intrusive event are mapped immediately to the southwest, west and northwest. Surficial deposits of the Kingsbury basin are not shown. Includes a discussion of the lithologic characteristics of the Colorado shale (sandstone and sandy shale beds are common lower in the section.) No discussion of hydrology included.

Kleinschmidt Lake.

Bibliographic source: U.S. Geological survey compilation of Blackfoot Valley references

Author: Weber, W.M. and I.J. Witkind

Title: Reconnaissance geologic map of the Browns Lake quadrangle, Powell County, Montana

Series: U.S. Geological Survey Open-file report 79-439

Date: 1979

Detailed surficial geologic mapping at 1:24,000 scale shows

Kleinschmidt Lake underlain by "Younger Pinedale" till of the North Fork provenance. The contact with the outwash gravels forming Kleinschmidt Flat is about 1 mile northeast of Kleinschmidt Lake. No information regarding stratigraphic relations is provided, but from surface relationships it appears possible that advance outwash deposits might underlie till in the vicinity of Kleinschmidt Lake.

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R., R.L. Earhart, J.W. Whipple and J.E. Harrison

Title: Geologic and structure map of the Choteau 1 degree X 2 degree quadrangle, Western Montana.

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-1300

Date: 1982

Regional compilation of bedrock geologic mapping at 1:250,000 scale shows the North Fork Blackfoot source area for the North Fork till to be underlain by Proterozoic (Belt) formations from the Spokane Formation through the Bonner Formation, including large areas of Helena Formation (dominantly carbonate lithologies) in the lower and middle basin. The upper basin includes areas of undifferentiated Cambrian and Devonian rocks.

LaFoe Lake

Bibliographic source: Geoindex lat-long search

Author: Johns, W.M.

Title: Geology and mineral deposits of Lincoln and Flathead counties, Montana

Series: Montana Bureau of Mines and Geology Bulletin 79

Date: 1970

Regional mapping at scale of approximately 1:125,000 shows the entire contributing drainage underlain by the calcareous and dolomitic Wallace Formation of Proterozoic Y (Belt) age. The Quartz Creek Fault, a normal fault downdropped to the west, is shown immediately underlying the Lafoe Lake wetland, raising the

possibility that the wetland may be structurally controlled in some sense.

This map shows only larger areas of surficial deposits, and provides no information on Quaternary sediments in the Lafoe Lake area.

Bibliographic source: None - DHES collection

Author: Rabe, F.W., R.L. Bursik and E.B. Cantor

Title: Classification and monitoring of wetlands in established and proposed natural areas.

Series: Project report on USDA Forest Service Intermountain Research Station Proposal #89009.

Date: 198?

This report provides a partial chemical analysis from June of 1987 and results of biological inventory of LaFoe Lake.

Lahrity Lake

Bibliographic source: None - Personal collection

Author: Dea, Peter.

Title: Glacial geology of the Ovando Valley, Powell County, Montana

Series: University of Montana Master's Thesis in Geology

Date: 1982

Detailed surficial geologic mapping at approximately 1:40,000 scale shows Lahrity Lake underlain by late Pleistocene till of the Monture Creek advance. Till and outwash of the Clearwater advance are mapped on the flanks of Monture Hill, and appear to be shown underlying the Lahrity Lake Southwest site. This is a stratigraphically complex area where glacial deposition was probably strongly influenced by the presence of Monture Hill.

Bibliographic source: Personal collection

Author: Lesica, Peter

Title:

Series: None

Date:

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R., R.L.Earhart, J.W.Whipple, and J.E. Harrison

Title: Geologic and structure map of the Choteau 1 degree X 2 degree quadrangle, western Montana

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-1300

Date: 1982

Regional compilation of bedrock geology at 1:250,000 scale shows Monture Hill outcrops in the immediate vicinity of Lahrity Lake to be the Snowslip Formation of Proterozoic Y (Belt) age. The snowslip Formation is described as interbedded argillite and siltite with minor fine-grained quartzite, pebble conglomerate and oolitic limestone.

Probable source areas for surficial glacial sediments in the Monture Creek drainage are shown as underlain by Belt Series sediments ranging from the Spokane Formation to the McNamara Formation, including large areas of the dominantly carbonate Helena Formation.

Between Monture Hill and the mountain front to the north, mapping shows several small patches of exposed valley-fill sediments ("lake beds") of mid to late Tertiary (Oligocene to Miocene) age. Elsewhere, Tertiary sediments are covered by glacial drift. Tertiary sediments are described as variable but dominantly fine-grained in character, locally calcareous and locally fossiliferous. In the Upper Blackfoot (Lincoln) area, similar sediments are described as pyritic. [See Indian Meadows entries.]

Lahrity Lake Southwest

See Lahrity Lake entries.

Lake Bowdoin (3 sites)

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Bergantino, R.N.

Title: Altitude of the top of the Claggett Shale, Glasgow 1 degree X 2 degree quadrangle.

Series: MBMG Open-file report 182

Date: 1987

Regional map compilation at 1:250,000 scale shows the natural catchment of Lake Bowdoin to be underlain by the Claggett Shale of Late Cretaceous age. Some contributing areas to the south may be underlain by the Late Cretaceous Judith River Formation, which overlies the Clagget Shale. Lake Bowdoin is shown to overlie the Bowdoin(?) structural dome southwest of it's apex.

This map has no accompanying text or hydrologic information. Surficial deposits are not shown.

Bibliographic source: U.S. Geological Survey request

Author: Lambing, J.H., W.E. Jones and J.W. Sutphin

Title: Reconnaissance investigation of water quality, bottom sediment and biota associated with irrigation drainage in the Bowdoin National Wildlife Refuge and adjacent areas of the Milk River basin, northeastern Montana, 1986-87

Series: U.S. Geological Survey Water-Resources Investigations Report 87-4243

Date: 1987

This initial reconnaissance investigation included ground-water data from two sites south and southeast of Bowdoin, surface water samples from the Dodson South Canal and from 3 sites within Bowdoin, along with Lakeside and Dry Lake Units. Sediment samples were collected from 4 sites in Bowdoin, including one near the DHES "Lake Bowdoin North Shore" site, and from Dry Lake and Lakeside Units.

This publication includes a geologic map of the Lake Bowdoin area which shows a band of alluvium, linking the Beaver Creek alluvium with the Milk River alluvium, passing just south of Lake Bowdoin. There is no apparent reference to the characteristics of this

alluvium in text of tables.

The publication also includes an exellent schematic of water supply and routing options within the Lake Bowdoin Refuge.

Lake Mason.

Bibliographic source: Geoindex lat-long search.

Author: Zimmerman, E.A.

Title: Preliminary report on the geology and ground water resources of parts of Musselshell and Golden Valley counties, Montana.

Series: MBMG Information Circular no. 15

Date: 1956

Another early and minimal MBMG ground water effort. Map shows Lake Mason entirely underlain by "alluvium", which includes lacustrine deposits. Text describes "alluvium" of the Lake Mason basin as up to 40 feet thick but high in silt content, with small well yields.

The "alluvium" (or lacustrine silts) of the Lake Mason basin are mapped as overlying the Lance formation throughout. The Lance (uppermost Cretaceous) is composed of repeated sequences of sandstone, shale, clay and coal. The sandstone intervals are described as dependable but relatively low-yield aquifer(s). Inferred structure (not shown on map) appears to be anticlinal, so ground water discharge to the basin may be important.

Extensive areas of terrace gravels underlie higher portions of the basin, especially in the north. Extensive areas of Bearpaw Shale around basin margins, some Judith River Formation exposed. [Some proper structural mapping would be useful.]

Ground water from the Lance formation is described as relatively mineralized compared to Eagle and Kootenai aquifers. Generally, Lance Formation groundwater (6 samples) is relatively sodic and sulfate rich.

Bibliographic source: Geoindex lat-long search

Author: Reeves, Frank

Title: Geology of the Cat Creek and Devils Basin oil fields and adjacent areas in Montana

Series: USGS Bulletin 786-B

Date: 1927

This is a detailed (for it's time) report on the structure and stratigraphy of this area but includes no hydrology or hydrogeology. Lake Mason is at the southwestward extremity of the map area (map scale of 1:125,000), shown within an extensive area of undifferentiated surficial deposits. Upgradient areas of South Willow Creek shown with extensive areas of terrace gravels elevated above drainages. Lance Formation (transitionally overlying Bearpaw Shale) the principal bedrock outcrop shown in the basin.

Structural contours on the Third Cat Creek Sand of the Kootenai Formation show Lake Mason near the axis of syncline plunging slightly southward(??)

Lake Thibadeau Northeast

Bibliographic source: None, default reference

Author: Ross, Andrews and Witkind

Title: Geologic map of Montana

Series: None(?)

Date: 1955

Regional compilation at 1:500,000 scale shows the entire contributing basin underlain by the Bearpaw Shale of Late Cretaceous age. This map provides no useful information regarding surficial deposits. The site is within the limits of Pleistocene glaciation and is presumably underlain by till (presumably calcareous) of unknown thickness.

Neither automated searching of the Geoindex database nor manual searching of the MBMG publications index revealed any more useful geologic mapping of this area.

Lakeside.

See Lake Bowdoin entries.

Lamesteer

Bibliographic source: Geoindex lat-long search

Author: Ellis, M.S.

Title: Geologic map of the Powder River basin and surrounding area, Wyoming, Montana, South Dakota, North Dakota and Nebraska

Series: Miscellaneous Field Studies Map MF-2095

Date: 1989

Regional mapping at 1:500,000 scale limits the usefulness of this map. Refuge site is shown underlain by the Tongue River Member of the Fort Union Formation.

Bibliographic source: Geoindex lat-long search

Author: Vuke-Foster, S.M., R.B. Colton, M.C. Stickney, E.M. Wilde, J.E. Robocker and K.C. Christensen

Title: Geology of the Baker and Wibaux 30 X 60-Minute quadrangles, eastern Montana and adjacent North Dakota

Series: Montana Bureau of Mines and Geology Geologic Map 41

Date: 1986

Geologic mapping at 1:100,000 scale shows the reservoir and most of upper Lame Steer Creek underlain by the "third member" (from the bottom - Tongue River equivalent?) of the Fort Union Formation, with sandstone, coal and sandstone/siltstone/mudstone lithofacies described. There is no map indication of which of these lithofacies underlies the refuge site. Headwater areas east of the Refuge are underlain by the "fourth member" of the Fort Union, dominantly sandstone with thinner interbeds of nonexpansive clay.

Bibliographic source: Montana Bureau of Mines and Geology Publications Catalog

Author: Taylor, O.J.

Title: Ground-water resources along the Cedar Creek anticline in Eastern Montana

Series: Montana Bureau of Mines and Geology Memoir 40

Date: 1965

Geologic mapping at 1:175,000 scale shows the Lame Steer drainage as undifferentiated Fort Union Formation. Structural contouring shows the basal Fox Hills sandstone at an elevation of about 1930 feet in the vicinity of the Refuge, dipping northeastward down the eastern limb of the structure. Potentiometric mapping provides little information on the east side of the anticline; there is no indication of flowing wells nearby.

The text speaks almost entirely to aquifer characteristics and drawdown modeling in the Hell Creek/Fox Hills sandstone and does not discuss Fort Union or surficial aquifers. Water chemistry data for the Hell Creek/Fox Hills aquifer is included.

Lavina DOT Wetland Mitigation Site

Bibliographic source: Geoindex lat-long search

Author: Ellis, A.J. and O.E. Meinzer

Title: Ground water in Musselshell and Golden Valley Counties, Montana

Series: USGS Water-Supply Paper 518

Date: 1924

Regional mapping at 1:250,000 scale shows the site underlain by the Judith River Formation, with upland areas to the north exposing Bearpaw Shale and Lance Formation. There is no information regarding the Musselshell alluvium in the vicinity.

LeBeau Creek South.

Bibliographic source: Geoindex latlong search

Author: Harrison, J.E., E.R. Cressman and J.W. Whipple

Title: Preliminary geologic map of part of the Kalispell 1 X 2 Degree Quadrangle, Montana.

Series: U.S. Geological Survey Open-File Report 83-502

Regional mapping at 1:250,000 scale shows the LeBeau area underlain by middle Belt (Proterozoic Y) formations, with the Spokane and Empire Formations (dominantly clastic lithologies) at lower elevations and large areas of Helena Formation (dominantly calcareous and dolomitic lithologies) underlying topographic highs. Numerous northwest trending normal faults (structural elements of the "Rocky Mountain Trench") cross the general area.

Surficial deposits are only broadly differentiated at this scale.

Lee Metcalf National Wildlife Refuge

Bibliographic source: Geoindex lat-long search

Author: McMurtrey, R.G., R.L. Konizeski, M.V. Johnson and J.H. Bartells

Title: Geology and Water Resources of the Bitterroot Valley, Southwestern Montana

Series: U.S. Geological Survey Water-Supply Paper 1889

Date: 1972

Regional geologic mapping at 1:125,000 shows the refuge underlain by modern Quaternary alluvium of the Bitterroot River. "Low terrace alluvium", including probable fan material of the Burnt Fork and Ambrose Creek, is shown just to the east. Tertiary outcrops are shown three miles or more to the east. Potentiometric mapping at the same scale interprets a potentiometric high beneath the Burnt Fork. Water table depth at the time of mapping shown to be 5 feet at a well adjacent to sample site. Tabulated chemical analyses show dilute (<300 mg/l TDS) calcium bicarbonate ground water types beneath flood plain and terrace surfaces. Transmissivities are reported to be high, with well yields reported greater than 250 gallons per minute.

Long Lake WPA

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of surficial glacial features at 1:500,000 scale shows the Long Lake wetland near a mapped ice-marginal limit passing through Sunburst. Willshaw Flats appears to be shown as an upstream part of a major mapped drainage way connected southward to the Marias River valley.

Bibliographic source: None, default reference

Author: Ross, Andrews and Witkind

Title: Geologic map of Montana

Series: None

Date: 1955

Regional compilation at 1:500,000 scale shows the basin underlain by Colorado Shale of late Cretaceous age. Mapping at this scale provides no information regarding surficial deposits. Field observations indicate the area is underlain by glacial and lacustrine deposits of unknown thickness.

Mallard Pond

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Bergantino, R.N.

Title: Prequaternary geology of the Wolf Point 1 degree by 2 degree quadrangle.

Series: MBMG Open-file report 171

Date: 1986

Regional compilation at 1:250,000 scale shows the glacial deposits of the wetland site to be underlain by undifferentiated Fort Union Formation of early Tertiary (Paleocene) age.

Bibliographic source: Montana Bureau of Mines and Geology

Author: Bergantino, R.N.

Title: Quaternary geology of the Wolf Point 1 degree X 2 degree quadrangle.

Series: MBMG Open-file report 172

Date:

Compilation at 1:250,000 scale shows Mallard Pond near the mapped contact between Clear Lake aquifer outwash deposits and a body of till to the west of Long Lake.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Donovan, J.J.

Title: Ground-water geology and high-yield aquifers of northeastern Montana

Series: MBMG Open-file report 209

Date: 1988

See Brush Lake entry for description of the study. Aquifer extent map at 1:100,000 scale shows Mallard Pond within the lateral boundaries of both the Clear Lake Outwash aquifer and the preglacial Missouri terrace gravels. Mallard Pond is listed but not classified according to groundwater outflow.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index.

Author: Reiten, J.C.

Title: Water Quality of selected lakes in eastern Sheridan County, Montana.

Series: MBMG Open-file report 244

Date: 1991(?)

Mallard Pond is included as on of this study's sample sites. 1990 sampling indicates a substantial salinity gradient between sampling

points in this small lake (nearly 100% difference in specific conductance). No historical (pre-1990) water quality data are given.

Mary's Frog Pond

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Sahinen, U.M.

Title: Mines and mineral deposits of Missoula and Ravalli Counties, Montana

Series: Montana Bureau of Mines and Geology Bulletin 8.

Date: 1957

Generalized geologic map at a large scale appears to show Mary's Frog Pond underlain by undifferentiated Ravalli Group formations of Proterozoic Y (Belt) age, just across the contact from the granitic rocks of the Cretaceous-aged Idaho batholith. [This is an ambiguous map scale but was corroborated by a larger-scale map of the area, reviewed quickly once and not found since.]

Bibliographic source: None - DHES collection

Author: Rabe, F.W., R.L. Bursik and E.B. Cantor

Title: Classification and monitoring of wetlands in established and proposed natural areas.

Series: Project report on USDA Forest Service Intermountain Research Station Proposal #89009.

Date: 198?

This document contains a partial chemical analysis dating from June(?) or July(?) of 1987, along with biological inventory data. The site descripiton refers to the basin as a "deep glacial scour" but provides no actual depth measurement.

Medicine Lake

Bibliographic source: Geoindex lat-long search

Author: Witkind, I.J.

Title: Quaternary geology of the Smoke Creek - Medicine Lake - Grenora area, Montana and North Dakota

Series: USGS Bulletin 1073

Date: 1959

Geologic mapping at 1:62,500 shows the area to be underlain by outwash deposits of late Wisconsin ("Mankato") age. The adjacent margins of the Dagmar Channel are shown underlain by extensive kame terrace deposits. Reconstruction of the late Wisconsin maximum ice extent shows the southern margin just south of Medicine Lake. The entire area is shown as an elongate southwestward oriented lobe, with Big Muddy Creek north of Medicine Lake largely ice-free.

Mikillop Creek Wetland

Bibliographic source: Geoindex lat-long search

Author: Johns, W.M.

Title: Geology and mineral deposits of Lincoln and Flathead counties, Montana

Series: Montana Bureau of Mines and Geology Bulletin 79

Date: 1970

Regional geologic mapping at 1:125,000(?) scale shows Mikillop Creek, including the sample site, underlain by undifferentiated glacial deposits. The contributing drainage basin is shown to be underlain the Wallace Formation on lower slopes and (probably) the Striped Peak Formation, both of Proterozoic Y (Belt) age. The Wallace Formation (Helena Formation equivalent) is dominantly calcareous and dolomitic; the Striped Peak Formation (Missoula Group) is composed mainly of argillitic and quartzitic lithologies.

Two mapped normal faults are shown intersecting very near or beneath the site. One is part of the dominant northwest trending series, parallel to the Thompson Lakes Fault to the north, and is shown extending up the (unnamed) south fork of Mikillop Creek and on to Horseshoe Lake, eventually merging with the Thompson Lakes Fault. The other trends east to northeast, crossing both forks of Mikillop Creek. Fault control of topography and of Mikillop Creek

wetland's distinct water chemistry are possibilities.

Mill-Willow.

Bibliographic source: Geoindex lat-long search.

Author: Konizeski, R.L., R.G. McMurtrey and A. Brietkrietz

Title: Geology and ground-water resources of the Deer Lodge Valley, Montana

Series: USGS Water-Supply Paper 1862

Date: 1968

Hydrogeologic mapping at scale of 1:62,500 shows the site underlain by undifferentiated Quaternary alluvium. Potentiometric interpretation shows adjacent reach of Silverbow Creek to be receiving ground-water discharge, but there were few data points to support this.

Gravimetric interpretation shows a gravity low centered just north of Opportunity, with relatively steeply increasing values eastward beneath the wetland area, showing thinning valley fill to the east from a maximum near valley axis.

Description of the characteristics of the alluvium includes the generalization that thickness averages about 20 feet on the Clark Fork floodplain, underlain by Pliocene sand and gravel. Beneath the "Willow Creek Flat", however, thickness is less than 10 feet and overlies volcanics. [Not clear exactly where the Willow Creek Flat is - possibly farther upstream on Willow Creek.]

Includes no water quality section.

Nine Pipe Reservoir (Outlet and Pothole)

Bibliographic source: Geoindex lat-long search

Author: Boettcher, A.J.

Title: Ground-water resources in the central part of the Flathead Indian Reservation, northwestern Montana.

Series: Montana Bureau of Mines and Geology Memoir 48

Date: 1982

Generalized surficial geologic mapping at 1:62500 scale shows only undifferentiated glacial deposits in the Nine Pipe area. Generalized potentiometric mapping shows a northward trough in regional surface beneath the reservoir. [This looks kind of strange and improbable, really.] Very generalized text, with no discussion of shallow flow systems in Nine Pipe area. Includes tabulated water chemistry from a number of wells in regional aquifer.

Bibliographic source: U.S. Geological Survey

Author: Slagle, S.E.

Title: Irrigation-canal leakage in the Flathead Indian Reservation, Northwestern Montana

Series: U.S. Geological Survey Water-Resources Investigations Report 92-4066

Date: 1992

This study used seepage-meter estimates of canal seepage at 5 sites on hydrogeologically distinct materials and a GIS of the canal system to generate canal seepage estimates for the entire Flathead Irrigation Projects system. One of these sites (the Charlo site) was on the Mission moraine, underlain by till of the same map unit as that underlying the Ninepipe sites several miles distant.

Observed differences in hydraulic conductivity correlated with differences in monitoring well response to canal head. In till facies of lower hydraulic conductivity, monitoring well response was subdued and only generally correlated with canal flows, while wells in more permeable till facies showed direct responses.

North Goose Lake

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Bergantino, R.N.

Title: Prequaternary geology of the Wolf Point 1 degree by 2 degree quadrangle.

Series: MBMG Open-file report 171

Date: 1986

Regional compilation at 1:250,000 scale shows the area underlain by undifferentiated Fort Union Formation of early Tertiary (Paleocene) age.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Bergantino, R.N.

Title: Quaternary geology of the Wolf Point 1 degree X 2 degree quadrangle.

Series: MBMG Open-file report 172

Date: 1986

Regional compilation at 1:250,000 scale shows North Goose Lake straddling the contact between till to the north and the Clear Lake aquifer outwash gravel beneath the southern two-thirds of the lake basin. All of the southern lake basin is shown underlain by outwash.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Donovan, J.J.

Title: Ground-water geology and high-yield aquifers of northeastern Montana

Series: MBMG Open-file report 209

Date: 1988

Blueline map of the extent of the Clear Lake aquifer shows North Goose Lake just outside of the 5-foot isopach of outwash sand and gravel, while the southeastern arm of the lake is within the 5 foot isopach. [Inference is that the broader area of outwash gravel

mapped by Bergantino, see above, is thinner than 5 feet.]

Both North Goose and the less saline Goose Lake are listed as restricted-outflow type lakes by Donovan.

Bibliographic source: Montana Bureau of Mines and Geology Publications Index.

Author: Reiten, J.C.

Title: Water Quality of selected lakes in eastern Sheridan County, Montana.

Series: MBMG Open-file report 244

Date: 1991(?)

This compilation of northeastern Montana lake water quality includes one quantitative analysis from the northern basin of Goose Lake (North Goose Lake by DHES site usage) dating from 1990. There are also 6 field specific conductance measurements from various points in the lake taken in 1990, and 7 from similar sites taken in 1984, showing an approximate doubling of specific conductance during that period.

North Widgeon Slough WPA

See Comertown Preserve entries.

Odell - Skull Creek Proposed RNA

Bibliographic source: Geoindex lat-long search

Author: Berger, B.R., L.W. Snee and W. Hanna

Title: Mineral resource potential of the West Pioneer Wilderness Study Area, Beaverhead County, Montana

Series: U.S. Geological Survey Miscellaneous Field Studies Map MF-

1585-A

Date: 1983

Geologic mapping at 1:50,000 scale shows the site underlain by glacial till, described as generally bouldery in character, covering bedrock units throughout the Odell Lake-Lacy Creek-Skull Creek Meadows area. Bedrock outcrops underlying the contributing basin are shown as Missoula Group formations (undifferentiated) of Proterozoic Y (Belt) age. Farther west large areas of various Cretaceous and Tertiary aged igneous rocks, mostly with granitic or granodioritic compositions, are shown. There are a few small scattered areas of Helena Formation (dominantly carbonate lithologies) of Proterozoic Y (Belt) age.

Mineral resource potential was evaluated for this study through stream sediment sampling for molybdenum, copper, lead, zinc and silver. The wetland site is just outside of a broad northwest-trending zone of identified potential for silver and gold mineralization containing several areas of identified molybdenum potential.

No direct structural information and no hydrologic information are provided.

Oilmont Wetland

Bibliographic source: Referenced L.K. Tuck (see Furnell references)

Author: Collier, A.J.

Title: The Kevin-Sunburst oil field and other possibilities of oil and gas in the Sweetgrass Arch, Montana

Series: U.S. Geological Survey Bulletin 812-B

Date: 1929

This document describes the structure and economic geology of the Kevin-Sunburst area as it was understood at the time. Structural contouring of the Madison Group shows the wetland site to be near the apex of the Kevin-Sunburst Dome. The publication does not include a geologic map per se but indicates the site is underlain by the Colorado Shale of Late Cretaceous age, possibly the Blackleaf Member.

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., R.W. Lemke and R.M. Lindvall

Title: Glacial map of Montana east of the Rocky Mountains

Series: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327

Date: 1961

Regional mapping of surficial glacial features at 1:500,000 scale shows the wetland site just within a lobe of a mapped glacial advance (apparently correlative with the advance repsponsible for the Sweet Grass Hills end moraine). The glacial deposits in the area are mapped mainly as "ground moraine", although there is a thin band of end moraine shown associated with the ice advance limit. Concentrations of drumlinoid features and crevasse-fill deposits are shown within this advance lobe. Beyond the mapped maximum position of this lobe, the surface is mapped as (presumably older) "ground moraine".

Bibliographic source: None, default reference

Author: Ross, C.P., D.A. Andrews and I.J. Witkind

Title: Geologic map of Montana

Series: U.S. Geological Survey, no series

Date: 1955

The wetland is shown to be underlain by a broad area of undifferentiated Colorado Shale. Generalized regional mapping provides no information regarding surficial deposits.

<u>Ontario Creek/Ontario Mine/Telegraph Creek</u>

Bibliographic source: Geoindex lat-long search

Author: Ruppel, E.T.

Title: Geology of the Basin quadrangle, Jefferson, Lewis and Clark and Powell Counties, Montana

Series: USGS Bulletin 1151

Date: 1963

Detailed geologic mapping (with emphasis on igneous units) at 1:48,000 scale shows the Ontario Creek and Telegraph Creek headwaters sites underlain by undifferentiated Elkhorn Mountain volcanics of late Cretaceous age. The wetland areas are near the contact with the Boulder batholith ("Butte Quartz Monzonite" unit) and are shown with a mappable (though probably thin) cover of undifferentiated glacial deposits.

The text includes extensive discussions of the mineralogy and petrography of different phases of igneous rocks mapped in the quadrangle. [Normative compositions of the Butte Quartz monzonite are Ca>Na>K.] Glacial deposits described include till and outwash; granitic cobbles and boulders in till are described as relatively deeply weathered, and the age of the glacial deposits is interpreted as early Wisconsin.

The Ontario Mine site is shown to be also underlain by the Butte Quartz Monzonite (Boulder Batholith) near the contact of a mass of aplite/alaskite underlying O'Keefe Mountain. The description of mines within the quadrangle does not appear to include the mine draining to the sample wetland, although the prospect is shown on the map.

Includes interesting mention of the 1898 injunction against mill in the Tenmile Creek drainage by the City of Helena to protect water supplies.

Pine Butte Fen

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R., R.L.Earhart, J.W. Whipple and J.E. Harrison

Title: Geologic and structure map of the Choteau 1 degree X 2 degree quadrangle, western Montana

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-1300

Date:

Regional compilation at 1:250,000 scale shows Pine Butte proper underlain by the Two Medicine and Horsethief Formations of Late Cretaceous age. Ridges to the west of the fen are underlain by the older Two Medicine Formation and underlying Virgelle Sandstone and

Telegraph Creek Formation, also of Late Cretaceous age. The Teton River canyon, presumed to be part of the source area for fluvial and glaciofluvial sediments underlying the fen, is underlain by numerous intercalated thrust fault slices of Mesozoic and Paleozoic rocks, including large areas of Mississippian-aged Madison Group limestone. The surficial sediments of the fen itself are shown to conceal the trace of the easternmost mapped thrust fault.

Bibliographic source: None - personal communications.

Author: Nimick, D.A., R.S. Rasmussun, W.W. Woessner and J. Schmidt

Title: Geologic and hydrologic investigations at Pine Butte and McDonald Swamps, Teton County, Montana.

Series: Unpublished report to The Nature Conservancy Montana Field Office.

Date: 1983

This report documents a reconnaissance-level investigation of the geologic, hydrologic and geometric controls on the formation and behavior of the Pine Butte and McDonald fens. The deposition of glacial and post-glacial sediments forming the aquifer supporting the fens is described, and hydrologic data including synoptic discharge measurements along the losing reach of the Teton River, potentiometric data from piezometers completed within and beneath the fen sediments, and discharge data for streams draining the fen are provided and discussed. (Streams draining the fen are described as perennial.) Very rough calculations of ground-water flux through the Pine Butte fen system are offered, and some limited qualitative interpretations of bedrock aquifer relationships are provided. (Bedrock is considered to be an unimportant contributor to the hydrologic system of the fen.)

The basic qualitative interpretation of the study is that ground-water discharge from the underlying unconsolidated aquifer system provides hydrologic support for the fen, and that seepage loss from the Teton River upgradient from the fen provides the largest component of recharge to the unconsolidated aquifer.

Sands WPA

Bibliographic source: Geoindex lat-long search

Author: Hearn, B.C. Jr.

Title: Geologic and tectonic maps of the Bearpaw Mountains area, north-central Montana.

Series: USGS Miscellaneous Investigations Series I-919

Date: 1976

Detailed regional geologic mapping at 1:125,000 scale shows the sample site and most of Halfway Lake underlain by the Judith River Formation of late Cretaceous age. The northernmost arm of the lake extends across a minor normal fault and into a small graben preserving late Cretaceous Bearpaw Shale and a small area of Tertiary volcanic rocks.

The contributing basin is underlain mainly by Judith River Formation, with secondary but substantial areas of Bearpaw shale and Tertiary-aged volcanic flows, and minor areas of Colorado Shale and Eagle Formation.

No direct information regarding hydrology is provided.

Schrammeck Lake

Bibliographic source: Montana Bureau of Mines and Geology Publications Index

Author: Fox, R.D.

Title: Geology and ground-water resources of the Cascade-Ulm area, Montana

Series: Montana Bureau of Mines and Geology Bulletin 52

Date: 1966

Geologic mapping at 1:62,500 scale shows Schrammeck Lake and most or all of it's contributing basin underlain by the Bootlegger (upper) member of the Blackleaf Formation (of the Colorado Group) of early Cretaceous age. Within the map area, regional dips are to the west and the Bootlegger is unconformably overlain by the Marias River Formation of late Cretaceous age. The map shows no mapped structures in the Schrammeck Lake area other than bedding orientation.

The Bootlegger Member is described as "interbedded black shale, greenish bentonite, brownish sandstone and chert pebble conglomerate". Bentonitic outcrops are described as exhibiting salt efflorescences. Chert pebble conglomerates are believed to have been derived from erosion of the Permian-aged Phosphoria Formation.

No mappable surficial deposits are shown in the Schrammeck Lake basin. There is a large area of dune sand shown several miles to the north, marginal to the Missouri River floodplain.

The text includes a very interesting description of springs discharging from the Bootlegger member. These are described as numerous in the area, but of low yield and poor quality, typically with salt efflorescences. Geyser Creek just north of Schrammeck Lake is named for groundwater discharge features in bentonitic Bootlegger Formation, forming holes and depositional cones.

The few water quality analyses provided do not include any from the Bootlegger Member. There is one analysis from a well in the Flood Member (basal sandstone) of the Blackleaf. It has subequal concentrations of divalent and monovalent cations, nearly equal bicarbonate and sulfate concentrations, and TDS of 1078 mg/l.

Spidel WPA

Bibliographic source: Geoindex lat-long search

Author: Ellis, M.S.

Title: Geologic map of the Powder River basin and surrounding areas...

Series: USGS Miscellaneous Field Studies Map MF-2095

Date: 1989

Regional mapping at a scale of 1:500,000. See other entries under this title.

Bibliographic source: Geoindex lat-long search

Author: Ellis, A.J. and O.E. Meinzer

Title: Ground water in Musselshell and Golden Valley Counties, Montana

Series: USGS Water-supply paper 518

Date: 1924

Regional mapping at a scale of 1:250,000 includes the sample site at southern extremity of map coverage. Structural interpretation

shows the Spidel basin lying on the western limb of the Bull Mountains structural basin, immediately underlain by the Lance Formation, with Bearpaw Shale and Judith River Formation to the west and Fort Union Formation to the east. The basin itself is mapped as an extensive area underlain by lacustrine (or paludal??) deposits.

Page 7 includes an interesting discussion of the Lake Basin and Comanche Lake structural impoundments but does not discuss the Spidel basin. Page 40-41 includes water chemistry from a number of Lance Formation wells but none from the immediate township.

The report is organized with hydrogeologic descriptions by township. The inventory for T5N R23E includes one well completed in section 28, completed somewhere between 75 and 116 feet, and one dug well in section 30, both considered to be finished in the Lance, both yielding adequate domestic supply. No records of water levels are included.

Swamp Gulch

Bibliographic source: Geoindex latlong search

Author: Whipple, J.W., M.R. Mudge and R.L. Earhart

Title: Geologic map of the Rogers Pass area, Lewis and Clark County, Montana.

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-1642

Date: 1987

Detailed bedrock geologic mapping at 1:48,000 scale shows Swamp Gulch itself underlain by the dominantly clastic Spokane Formation and the transitional Empire Formation (Proterozoic Y), with none of the dominantly calcareous and dolomitic Helena Formation within the watershed. The outcrops at the mouth of the drainage are mapped as Proterozoic Z intrusives (diorite). A portion of the Mike Horse Stock (Paleocene/Eocene monzonite porphyry or quartz monzonite porphyry).

Upgradient contributing drainages (Pass Creek, Anaconda Creek, etc.) are underlain by the same lithologies, with the addition of small areas of Helena Formation at higher elevations along the divides.

Structurally within the Hoadley Thrust Plate, one of a series of stacked thrust plates shown on the map area. Dips shown are low

to moderate to the NE to NW.

The Quaternary deposits of the sample wetland are shown simply as alluvium.

This is the best bedrock map of the area reviewed.

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R. and R.L. Earhart

Title: Bedrock geologic map of part of the Northern Disturbed Belt, Lewis and Clark, Teton, Pondera, Glacier, Flathead, Cascade and Powell Counties, Montana

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-1375

Date: 1983

Regional geologic mapping at 1:125,000 scale shows the Swamp Gulch area underlain predominantly by Proterozoic Y Spokane Formation, with Proterozoic Y Empire Formation probably at upper elevations in the headwaters. The Proterozoic Z diorite also is exposed in the Pass Creek and Swamp Gulch(?) drainages, and Tertiary hornblende monzonite and monzonite porphyry are intruded into the proterozoic rocks of the region.

The Empire and Spokane formations are described as predominantly clastic lithologies, but including calcareous cement and carbonate interbeds, described as limestone in the Spokane and both dolomite and limestone in the Empire Formation.

Bibliographic source: None - agency file search

Author: Dollhopf, D.J., J.D. Goering, R.B. Rennick, R.B. Morton, W.K. Gauger, J.B. Guckert, P.M. Jones, K.C. Cooksey, K.E. Bucklin, R. Weed, and M.M. Lehman

Title: Hydrochemical, vegetational and microbiological effects of a natural and a constructed wetland on the control of acid mine drainage.

Series: Montana Department of State Lands Abandoned Mines Reclamation Bureau Final Report on contract 2-6000-230, performed by the Montana State University Reclamation Research Unit.

Date: 1988

This document provides detailed analysis of the distribution and

geochemical occurrence and control of metals derived from the abandoned Carbonate Mine in the Swamp Gulch wetland. The study included measurements of hydraulic conductivity in the wetland sediments, potentiometric mapping of the shallow ground-water flow system, discharge data from Swamp Gulch, metals uptake data for wetland vegetation and other data. The study compared metals immobilization by the natural Swamp Gulch wetland with that in the constructed wetland at Sand Coulee, an acid mine drainage site in Cascade County. The Swamp Gulch site was found to be much more effective, apparently because it supports healthier populations of sulfate-reducing bacteria effective in precipitating metal sulfides.

Swan River Proposed RNA

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R., R.L. Earhart, J.W. Whipple and J.E. Harrison

Title: Geologic and structure map of the Choteau 1 degree X 2 degree quadrangle, western Montana.

Series: U.S. Geological Survey Miscellaneous Investigation Series Map I-1300.

Date: 1982

Regional map compilation at 1:250,000 scale shows the upland slopes above the site to be underlain entirely by the Helena Formation (Belt Supergroup) of Proterozoic Y age. The Helena Formation consists predominantly of carbonate lithologies (limestone and dolomite) and generally calcareous clastic sediments.

Bibliographic source: Geoindex lat-long search

Author: Witkind, I.J. and M. Weber

Title: Reconnaissance geologic map of the Big Fork-Avon environmental study area, Flathead, Lake, Lewis and Clark, Missoula and Powell counties, Montana

Series: USGS Miscellaneous Investigations Map I-1380

Date:

Regional geologic mapping at 1:125,000 scale emphasizing surficial

geology. Sample site is shown to be near the contact of modern alluvium and "valley facies" of late Pleistocene till. The till facies is described as loose and having a sandy matrix. The knob elevated above the valley floor is shown as a kame deposit on this map, rather than a drumlin as it is described elsewhere. There is no subsurface or hydrologic information included.

Telegraph Creek.

See entries under **Ontario Creek.**

Tew WPA

Bibliographic source: Geoindex lat-long search

Author: Ellis, M.S.

Title: Geologic map of the Powder River basin...

Series: USGS Miscellaneous Field Studies Map MF-2095

Date: 1989

Regional compilation at 1:500,000 scale. See other entries.

Bibliographic source: Geoindex lat-long search

Author: Woolsey, L.H., R.W. Richards and C.T. Lupton

Title: The Bull Mountain coal field, Musselshell and Yellowstone Counties, Montana

Series: USGS Bulletin 647

Date: 1917

Regional mapping at 1:125,000 scale shows the Tew WPA apparently underlain by the Lebo Shale member of the Fort Union Formation, with mappable accumulations of "alluvium" (probably lacustrine or paludal sediments) shown within two or three nearly-closed basins. The text provides no description of these surficial sediments nor any discussion of the hydrologic characteristics of the map area.

Tooley (aka Toole) Lake

Bibliographic source: Geoindex lat-long search

Author: Coffin, D.L., A. Brietkrietz and R.G. McMurtrey

Title: Surficial geology and water resources of the Tobacco and Upper Stillwater River Valleys, Northwestern Montana

Series: Montana Bureau of Mines and Geology Bulletin 81

Date: 1971

Surficial geologic mapping at approximately 1:100,000 scale shows Tooley Lake underlain by glaciolacustrine sediments of Glacial Lake Kootenai(?). Nearby exposures of glaciolacustrine sediments are up to 300 feet in thickness. Glaciolacustrine sediments in the study area are described as predominantly silt and very fine sand with thin (less than 1 foot) clay interbeds. Spring discharges from these sediments are described, but well completions are reportedly rare and avoided by drillers due to heaving tendencies.

Upslope areas amounting to approximately half of the contributing drainage are underlain by drumlin - marked till, described in near-outcrop areas (as this is) as being boulder-rich [although the drumlins imply it is still predominantly fine - grained.]

Specific conductance measurements collected in June and October of 1968 were 670 and 800 microsiemens, respectively. No quantitative water chemistry from the lake or from wells in the immediate vicinity are provided.

Analog steady-state ground water flow model (!!), with head apparently tied to Tooley Lake, produced steep potentiometric gradient between the lake and the Kootenai River.

Bibliographic source: Geoindex lat-long search

Author: Johns, W.M.

Title: Geology and mineral deposits of Lincoln and Flathead Counties, Montana

Series: Montana Bureau of Mines and Geology Bulletin 79

Date: 1970

Relatively detailed pre-Cenozoic geologic mapping shows slopes to the west underlain by undifferentiated Ravalli Group rocks of Proterozoic Y (Belt) age. Ravalli Group rocks are described as

predominantly argillites and quartzites, with important calcareous units only near the top of the section. Upper basins of Dodge Creek and Young Creek, which bracket the small drainage feeding Tooley Lake, drain areas of undifferentiated Piegan Group (carbonate rich and pyritic in the Siyeh Formation) the Siyeh Formation proper.

Bibliographic source: None - DHES collection

Author: Rabe, F.W., R.L. Bursik and E.B. Cantor

Title: Classification and monitoring of wetlands in established and proposed natural areas.

Series: Project report on USDA Forest Service Intermountain Research Station Proposal #89009.

Date: 198?

This document provides field chemical characteristics (pH and conductivity) for Tooley Lake (known as Toole Lake in this report) in July 1988. The report also provides an inventory of the biological characteristics of the lake.

Townsend Valley Wetland

Bibliographic source: Geoindex lat-long search

Author: Lorenz, H.W. and R.G. McMurtrey

Title: Geology and occurrence of ground water in the Townsend Valley, Montana.

Series: U.S. Geological Survey Water-Supply Paper 1360-C

Date: 1956

Regional geologic mapping at 1:96,000 scale shows the area underlain by undifferentiated quaternary alluvium. Generalized potentiometric mapping at 1:62,500 scale shows the site near or within an area identified as waterlogged at the time of the study. Tabulated water level records indicate wells in the site section fluctuated 6 -10 feet during the investigation, with maximum water levels on the order of 15 feet.

Tabulated water chemistry for the Quaternary alluvium in the

general vicinity indicates unremarkable calcium/bicarbonate-to-mixed water types, generally under 1000 microsiemens/cm in conductivity.

Bibliographic source: Geoindex latlong search

Author: Freeman, V.L., E.T. Ruppel and M.R. Klepper

Title: Geology of part of the Townsend Valley, Broadwater and Jefferson Counties, Montana

Series: U.S. Geological Survey Bulletin 1042-N

Date: 1958

Geologic mapping at 1:48,000 scale shows the site underlain by Quaternary alluvium, differentiated from fan deposits, pediment deposits and older Pleistocene terrace gravels. The emphasis of this document is on pre-Quaternary formations, and only a brief description of the characteristics of the Missouri alluvium is provided.

Turtle Lake

(See Alkali Lake entry.)

Bibliographic source: None - DHES collection

Author: Rabe, F.W., R.L. Bursik and E.B. Cantor

Title: Classification and monitoring of wetlands in established and proposed natural areas.

Series: Project report on USDA Forest Service Intermountain Research Station Proposal #89009.

Date: 198?

This document provides a partial (and suspect?) chemical analysis from June of 1987 along with biological inventory data from Turtle Lake.

Upper Red Rock Lake.

Bibliographic source: Geoindex lat-long search

Author: Sonderegger, J.L., J.D. Schofield, R.D. Berg and M.L. Mannick

Title: The Upper Centennial Valley, Beaverhead and Madison Counties, Montana

Series: MBMG Memoir 50

Date: 1982

This study was instigated as an evaluation of the geothermal potential of the Centennial Valley and adjacent areas of the Upper Madison valley. The structural geology of the Centennial Valley is described in detail, and the stratigraphy and paleogeography of Cenozoic volcanic and volcaniclastic rocks also receives emphasis. Outcrops on the southern end of the Gravelly Range are dominantly the Huckleberry Ridge Tuff and other Quaternary volcanics mantling Paleozoic rocks. Outcrops are separated from the Lake by several miles of dune sand and Quaternary alluvium. Outcrops to the south across the Centennial fault are not mapped here but are described as including formations ranging in age from lower Cretaceous to Precambrian.

Ground-water chemistry from surficial aquifers on the north side of the valley (alluvium and aeolian sand) supports some mixing of deep-circulating geothermal water. Thermal imaging of the northern margin of Upper Red Rock Lake also supports some leakage of warm Madison Group ground water into the lake and nearby aquifers. Structural interpretation shows an inferred fault trace passing between Upper Red Rock and Swan Lakes, which is interpreted as the flow path for deeply circulating ground water discharge.

Geothermometry is interpreted as indicating only moderate reservoir temperatures of 45 degrees C or so (chalcedony thermometer).

Appendices include well summary and numerous water quality analyses which should be copied.

Bibliographic source: Geoindex lat-long search

Author: Witkind, I.J.

Title: Geologic map of the Centennial Mountains Wilderness Study area and contiguous areas, Idaho and Montana.

Series: USGS Miscellaneous Field Studies Map MF-1342-A

Date: 1982

Very good 1:50,000 scale map of the geology of the Centennials, but includes little mapping of the surficial deposits in the valley. Only the fan deposits along the mountain front are shown. Centennial scarp is mapped showing formations ranging from undivided Precambrian basement rocks up to Jurassic undivided near the divide.

Upper Stillwater River Wetland

Bibliographic source: Geoindex lat-long search

Author: Elliot, J.E.

Title: Geologic map of the southwest part of the Cooke City Quadrangle, Montana and Wyoming.

Series: U.S. Geological Survey Miscellaneous Investigations Series Map I-1084.

Date: 1979

Detailed bedrock geologic mapping at 1:24000 shows the Upper Stillwater wetland underlain by Holocene-aged alluvium, which overlies an extensive area of undifferentiated Pleistocene-aged glacial deposits. No descriptions of the characteristics or thickness of the surficial geologic units is provided.

Glacial sediments upgradient from the sampling site cover sedimentary rocks of Cambrian age (including the calcareous Meaghar and Pilgrim Limestones) and silicic to intermediate volcanic rocks (rhyodacite and latite) of early Tertiary (Eocene) age. Daisy Creek, an eastern tributary to the upper Stillwater River receiving acid mine drainage from the historic McLaren Mine, incises the glacial cover and exposes the Cambrian formations along it's upper channel.

The western margin of the wetland (as indicated by the extent of Holocene alluvium) and the upper Stillwater River above the sampling site are shown closely following a normal fault (downdropped to the east) which may exert some structural control on the drainage.

Bibliographic source: Geoindex lat-long search

Author: Lovering, T.S.

Title: The New World or Cooke City mining district, Park County, Montana

Series: USGS Bulletin 811-A

Date: 1929

This document emphasizes the petrology, mineralogy and economic geology of the New World District and adjacent areas. Geologic mapping at 1:31,360 scale is anachronistic, updated by Elliott (1979).

There is a very interesting description of native copper deposits found within organic-rich intervals of the upper Fisher Creek (?) alluvium near the lower Glengarry adit, across the Stillwater-Fisher Creek divide from the Upper Stillwater wetland. Lovering hypothesized bacterial reduction of oxidation products from exposed chalcopyrite nearby as the source. Lovering implies that this is a natural process not linked to mine drainage. Bacterial reduction was supported by an inoculation experiment resulting in the removal of copper from various copper sulfate solutions.

Lovering also describes extensive areas of limonitic cementation of post-Pleistocene(?) sediments on Red Mountain.

Wagner Basin RNA

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R.

Title: Bedrock geologic map of the Sawtooth Ridge quadrangle, Teton and Lewis and Clark counties, Montana.

Series: USGS Geologic Quadrangle Map GQ-381

Date: 1965

Wagner Basin is barely on the Sawtooth Ridge quad, and although it includes the Wagner Basin sampling site, it isn't completely clear whether the spring discharge point is within the area covered or not.

Wagner Basin is shown underlain by depositional sequence of

Kootenai, Morrison, Swift, Rierdon, Sawtooth, and Mississippian Castle Reef Dolomite(??). Dips are steeply westward. Possible aquifers include the Kootenai, Swift and Castle Reef Dolomite.

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R.

Title: Surficial geologic map of the Sawtooth Ridge quadrangle, Teton and Lewis and Clark counties, Montana

Series: USGS Geologic Quadrangle Map GQ-610

Date: 1967

Wagner Basin site is at the northern extremity of coverage by this sheet. Surficial deposits at the site are mapped as alluvium. Outwash deposits are mapped along western margin of the basin to the west of the wetland. Terrace gravels, reportedly about 20 feet thick, presumably Sun River gravels, are shown at the lower edge of the basin along Diversion Lake.

Bibliographic source: Geoindex lat-long search

Author: Mudge, M.R. and R.L. Earhart

Title: Bedrock geologic map of part of the northern Disturbed Belt, Lewis and Clark, Teton, Pondera, Glacier, Flathead Cascade and Powell Counties, Montana

Series: U.S. Geological Survey Miscellaneous Investigation Series Map I-1375

Date: 1983

Geologic mapping at scale of 1:125,000 shows the Wagner Basin area underlain by intercalated thrust fault slices of Madison Group, undifferentiated Mount Pablo Formation (Lower Cretaceous), Morrison Formation and Ellis Group (Upper Jurassic). Dips are westward at 30 to 65 degrees.

The Mount Pablo Formation consists of up to 90 meters of nonmarine sediments, including up to 10 meters of lacustrine limestone near the top of the section. The Ellis Group described as predominantly clastic marine sediments of varying lithology, including phosphatic beds. The description of Madison Group Formations includes dolomite increasing westward, but no mention of gypsum or other evaporites.

Warhorse Lake

Bibliographic source: Geoindex lat-long search.

Author: Perry, E.S.

Title: Artesian wells as a source of water for the Winnett Irrigation Project, Montana

Series: MBMG Miscellaneous Contributions no. 1

Date: 1932

This document has no plates, providing only a 1:126,720 (.5 inch/mile) line map with structure contours. The entire Warhorse basin is shown as Colorado Shale, with younger Cretaceous units outcropping far upgradient toward the Judith Mountains and downgradient on lower Boxelder Creek.

Perry discounts the importance of ground-water discharge to Fords Creek on structural grounds (dips are away from the drainage). Warhorse Lake itself occupies northwestward plunging synformal structure (Reeves, 1927) with no formations above the Colorado exposed, suggesting little likelihood of ground-water contribution.

Perry notes ubiquitous presence of gypsum (selenite) in the Colorado shale outcrops of the area.

Perry also noted that Warhorse was dry during the summer of 1941.

Bibliographic source: Geoindex lat-long search

Author: Reeves, Frank

Title: Geology of the Cat Creek and Devils Basin oil fields and adjacent areas in Montana

Series: USGS Bulletin 786-B

Date: 1927

See entry under Lake Mason also.

Warhorse Lake is near the northwestern corner of the map area. All of the catchment shown is underlain by Colorado Shale. Middle and upper Ford's Creek (which is/was diverted into Warhorse) is not mapped. Warhorse occupies a position near the axis of a minor syncline between the Kootenai Dome to the north and the McDonald

Creek anticline to the south.

Includes measured section of Colorado Shale from the nearby Kootenai Dome, with discussion of the lithologic characteristics of the notable marker beds within it, but no map indication of Lake Mason's position within the Colorado section.

Warm Springs Ponds (all sites)

Bibliographic source: Montana State Library subject file search

Author: Montana Department of Health and Environmental Sciences (prepared by CH2M Hill, Inc. and Chen-Northern, Inc.)

Title: Final Silver Bow Creek CERCLA Phase II Remedial Investigation Data Summary, Warm Springs Operable Unit

Series: Silver Bow Creek Investigation

Date: 1989

This document contains summaries and discussion of all data collected as part of the Remedial Investigation, along with the data themselves in two volumes of appendices. Analyses from numerous water and sediment sampling sites within the three Warm Springs Ponds are included in the data set. Contaminant concentrations in ground water are contoured for the ponds and surrounding areas. Algal counts and taxonomic distributions are included.

Bibliographic source: Montana State Library subject file search

Author: Montana Department of Health and Environmental Sciences (prepared MDHES and CH2M Hill)

Title: Draft Feasibility Study for the Warm Springs Ponds Operable Unit

Series: Silver Bow Creek Investigations

Date: 1989

This document contains analyses of alternative remediation plans considered for the Warm Springs Ponds and Mill-Willow Bypass areas. The report includes summaries of the geologic and hydrogeologic setting, pond history and contaminant transport pathways and mechanisms, sediment data, and risk assessment for human exposure. Aquatic life of the ponds is not an emphasis of this document.

Section 2 contains summary data (elevations, volumes, capacities of inlet and outlet structures, etc.) for the ponds, as well as statistical summaries of water and sediment chemistry data.

Bibliographic source: Geoindex lat-long search.

Author: Konizeski, R.L., R.G. McMurtrey and A. Brietkrietz.

Title: Geology and Ground-Water Resources of the Deer Lodge Valley, Montana

Series: U.S. Geological Survey Water-Supply Paper 1862.

Date: 1968

[See Mill-Willow for primary abstract.]

Geologic mapping at 1:62500 scale shows Tertiary sediments immediately to the west of the facility, which is underlain by alluvium of Silver Bow and Warm Springs(?) Creeks. The Ducks Unlimited site is underlain by alluvium of Warm Springs Creek. Reported water table depths range from 9 feet beneath the ponds, to 1 foot adjacent to ponds, to 7 feet in the vicinity of the DU pond.

Gravity interpretation shows a bedrock high along the valley margin to the south of the facility; it may continue northward beneath the ponds. Depth of total valley fill beneath the DU site is probably hundreds of feet, depth of Warm Springs Creek alluvial fan deposit probably thinning toward reported axial maximum of 20 feet, with Tertiary (channel facies??) material underlying fan deposits.

White Lake

See Brush Lake entries.

Yellowstone River at Miles City

Bibliographic source: Geoindex lat-long search

Author: Ellis, M.S.

Title: Geologic map of the Powder River basin and surrounding area..

Series: USGS Miscellaneous Field Studies Map MF-2095

Date: 1989

Regional compilation at a scale of 1:500,000. See other entries.

Bibliographic source: Geoindex lat-long search

Author: Colton, R.B., S.J. Luft and G.P. Cormier

Title: Photogeologic and reconnaissance geologic map of the Miles City quadrangle, Montana

Series: USGS Miscellaneous Field Studies Map MF-1682

Date: 1984

Surficial geologic mapping at 1:24,000 scale shows the site to be an abandoned side channel of the Yellowstone, developed along the edge of the modern Yellowstone floodplain and just below the Holocene/Pleistocene(?) terrace underlying Miles City. The map provides only a generalized description of the alluvial material, citing literature describing it's thickness as up to 15 meters.

The adjacent bedrock outcrops on both sides of the Yellowstone are mapped as the Tullock Member of the Fort Union Formation, which is described as lithologically similar to the overlying Lebo Member, but having a higher proportion of sandstones.

This map provides no description of the hydraulic characteristics of the map units.

Bibliographic source: Geoindex lat-long search

Author: Lewis, B.D. and R.S. Roberts

Title: Geology and water-yielding characteristics of rocks of the northern Powder River Basin, southeastern Montana

Series: USGS Miscellaneous Investigations Series Map I-847-D

Date: 1978

Regional mapping at 1:250,000 scale ends at the Yellowstone River, showing geology on the southern side only. Lower outcrops along the river are shown as the Tullock Member of the Fort Union Formation, with extensive Lebo Member outcrops and a broad upland area of the Tongue River Member to the southeast.

Descriptions of the hydraulic characteristics of the Yellowstone alluvium are generalized only, with reference to possible yields up to several hundred gallons per minute.

Bibliographic source: Geoindex lat-long search

Author: Torrey, A.E. and F.A. Swenson

Title: Ground-water resources of the lower Yellowstone River valley between Miles City and Glendive, Montana

Series: USGS Circular 93

Date: 1951

This report was part of the series of investigations designed to evaluate the effects of new irrigation projects along the lower Yellowstone River. Areas near Miles City, however, are shown as already irrigated at the time under the Tongue-Yellowstone Irrigation Project.

The Miles City area is underlain by a structural basin, with groundwater recharge to the west (the Porcupine Dome) and to the east (the Cedar Creek anticline) supporting flowing wells completed in the Fort Union and Hell Creek aquifers underlying the alluvium in the vicinity of Miles City.

Drainage problems on the Tongue-Yellowstone project were considered minimal at the time, following several decades of irrigation. Water level records are reported for several observation wells within the section of the sampling site, with levels ranging from about 7.5 to about 16 feet below the surface at the time.

Water quality sampling identified characteristic high-Na water quality from all flowing wells in the study area. It may be possible to identify mixed contribution to wetland water chemistry.

There is also a discussion of the geomorphology of terraces along the lower Yellowstone, with six terrace elevations above the modern floodplain identified.

Appendix D

Source Documentation for Hydrogeomorphic Database of the DEQ Wetland Characterization Sites

Location (Fields dlat, dlong, mlat, mlong, slat and slong).

Sampling locations are based upon Randy Apfelbeck's mapped site locations indicated on 7.5 minute USGS topographic quadrangle maps. In some cases sampling sites were marked on the topographic maps in the field during sampling; in other cases the maps were not used in the field, and locations were reconstructed later from field notes. In most cases these map locations are believed to be accurate to a tolerance of ±5 seconds latitude and longitude. At some sampling sites along low-angle, transient shorelines, accuracy may be less but probably is no worse than ±10 seconds latitude and longitude.

The translation of mapped sampling points to the 6-field DBase locations was done manually using mylar overlays on the topographic quadrangles. The overlay translation is believed to be precise within ± 2 or 3 seconds of latitude and longitude.

The ArcInfo point coverage of sample site locations is generated from the manually translated dBase location fields and carries the same accuracy and precision.

Elevation (Field Site el).

Site elevations (in feet above MSL) are derived from mapped elevations of the sampled wetlands shown on 7.5 minute topographic quadrangles. Visual interpolations of elevations between contour intervals are made where appropriate. Accuracy of the interpolated map elevations are dependent on map accuracy and contour intervals. Elevations in the dBase field are not modified to account for differences between water levels at the time of sampling and those in the photobase for the topographic quadrangles.

Maximum drainage basin elevation (Field basn max).

Maximum drainage basin elevations (in feet above MSL) were determined manually from topographic mapping. For sample wetlands with smaller drainage basins, basin maximum elevations were derived from 7.5 minute topographic quadrangles with contour intervals of 40 feet or better. For some sites with large contributing basin areas, maximum basin elevations were determined from small-scale topographic maps with contour intervals as large as 200 feet. In the case of wetland and lake basins with known substantial water imports (such as Ninepipe Reservoir), the basin is taken to include the areas contributing to source of the imports, and the drainage basin maximum elevation reflects areas contributing imported water.

Surface water inlet and outlet (Fields surf in and surf out).

Surface water inlet and outlet codes reflect the appearance of these features on the most current 7.5 minute USGS topographic quadrangle maps. In a few cases (the Blackfoot WPA for instance) field observations of inlet or outlet features disagree with map symbology. In these cases field observations prevail.

Reservoirs are coded as having surface water outlets even where spillways are known to convey water only periodically. All inlet and outlet streams, including those shown as non-perennial on the topographic quadrangles, are considered.

Hydrologic manipulation (Fields impound and import).

The existence of impoundments (dams or dikes) and water imports are coded on the basis of features shown on the most current 7.5 minute topographic quadrangles, supplemented with information gathered in the field and from land management agencies. The shortcomings of using topographic map data are recognized; nevertheless map data probably identify most of the significant hydrologic modifications of these types.

There are a handful of known sites (and probably others) where abandoned or breached structures which are no longer functional controlled water inputs and storage at one time, (e.g., Jarina). Where known, these types of wetlands are coded as lacking these structural features.

Mean Annual Evaporation rate (Field Evap)

The value entered in the Evap field is the Penman method value (in inches per year) for the MAPS database cell within which the sample site is located. The use of Penman values is not intended to suggest that they necessarily represent the best estimates of evaporative and evapotranspirative water loss from the sampled wetlands. The values are intended as relative indices of the intensity of evaporative forcing. Penman potential evaporation and Thornwaite potential evapotranspiration values are both available statewide through the MAPS atlas; when compared to pan evaporation data for 12 longer-term climatic sites, Penman values appear to be a more sensitive index of measured (pan) rates and are therefore considered a more useful value against which to evaluate wetland characteristics.

Mean Annual Precipitation (Field Mean pre)

The values entered in the mean precipitation field are the mean of the range of values (in inches per year) for the MAPS database cell within which the sample site is located. These MAPS values were in turn derived from the 1978 Soil Conservation Service compilation of Montana precipitation for the 30-year period 1941-70 (Caprio et al, 1994). The MAPS site values were compared to the

individual NOAA station records considered most representative of the individual wetland sites in order to evaluate longer historical records and more recent local climatic trends.

The use of mean cell values to approximate site mean annual precipitation is arbitrary and introduces error to this field. In mountainous areas with steep precipitation gradients and large precipitation contour intervals in the 1978 compilation, this error may be fairly large. There is probably a tendency to overestimate precipitation values relative to the 1978 interpolation in these cases, since the wetland site locations are probably biased toward lower elevations within the elevation range of any given MAPS cell.

Wetland Area (Field Wet Area)

Wetland areas for the sampled wetlands are derived from ArcInfo coverages of the sites. For smaller sites which do not appear as hydrographic features in the 1:100,000 RF3 coverages, wetland areas were digitized from 7.5 minute topographic sheets. In all cases and particularly for smaller sites or those with transient extent, precision is low. Areas may not reflect free water extent at the time of sampling, and are not intended to represent jurisdictional wetland areas.

Drainage Basin Area (Field Basin Area)

Drainage basin areas for the sampled wetlands (in acres) are derived from Arcinfo coverages of contributing catchment areas. For sites with smaller contributing basins (those covering 1 or 2 7.5 minute topographic quadrangles), basin boundaries were digitized from manually drawn boundaries on the 7.5 minute quads. For sites with larger contributing basins, boundaries were estimated from the 1:100,000 RF3 hydrographic coverage of Montana. For sample wetlands known to receive a large fraction of their water from interbasin imports (e.g, Lake Bowdoin, Ninepipe Reservoir, Homestead Lake), basin areas for the streams contributing imported water are included.

Surficial and bedrock geologic units (fields Surf geo and Bed geo.)

Surficial and bedrock geologic fields are occupied by the U.S. Geological Survey alphanumeric codes for geologic units in Montana. Geologic units were determined from the best available geologic mapping of the wetland, cited in the accompanying Annotated Bibliography of Wetland Site Geology. Geologic units are those interpreted to be underlying the wetland itself; other geologic units may underlie the contributing drainage basin.

The coding system does not include paludal or modern lacustrine sediments, which are a ubiquitous feature of the sample sites. The provisional codes 110"LAC", 111"LAC" or 112"LAC" are adopted for sites where (nonglacial) lacustrine sedimentation is

known or inferred to dominate the surficial geology of the site. Recent chemical sediments are also outside of the coding system and are not recognized in these database fields. Where no information regarding surficial deposit is available, this field is left blank.

Geologic units are specified at the lowest hierarchical level supported by the available information, which varies between sites. Thus a more general code (400BELT) may be used if a more specific one (400WLLC) cannot be determined from the available information. Where the wetland is known to be underlain by more than one geologic unit, the field is coded for the hierarchically lowest common stratigraphic division. For example, a wetland known to be underlain by both the Two Medicine and Telegraph Creek Formations (of the Montana Group) would be coded 211MNTN (the Montana Group). Where the wetland is known to be underlain by geologic units of different eras, the field is coded for the geologic unit having the greater extent within the drainage basin of the wetland.

Calcite, aragonite, dolomite and gypsum saturation indices. Aqueous solution composition and saturation indices were calculated using PCWATEQ, a DOS-driven version of the chemical equilibrium program WATEQF. Since dissolved analyses were conducted only for major components, no equilibrium calculations were performed for phases involving iron or other trace constituents. As applied, these solution equilibria are of interest mainly in identifying the theoretical saturation status of major carbonate and sulfate mineral phases. Analytical bicarbonate and carbonate concentrations were used in the WATEQPC input (Alkalinity Option 2); field dissolved oxygen measurements were used for calculating pE, and the Davies equation was used for all samples (including highly saline sites.)